GEOENVIRONMENTAL APPRAISAL AND ITS IMPACT ON GROUNDWATER OF AGRA METROPOLITAN CITY

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Certificate

This is to certify that the work presented in this dissertation entitled, **"Geoenvironmental Appraisal and Its Impact on Groundwater of Agra Metropolitan City"** has been carried out and completed under my supervision in the field of Hydrogeology/ Environmental Geology at the Department of Geology, Aligarh Muslim University, Aligarh.

This work is an original contribution to existing knowledge of the subject. I recommend that **Mr. Md. Naushad Khan** (Reg. No. 200357) be allowed to submit the dissertation for the award of the degree of **Master of Philosophy** in **Geology** of the Aligarh Muslim University, Aligarh.

Dkhurshid

(Dr. Shadab Khurshid)
Reader

Dedicated

to my

parents and

beloved uncle

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Chapter-1

Introduction

INTRODUCTION

The environment is defined as the sum of all external influences and conditions affecting life and development of organism. The environmental pollution can be defined as an undesirable or deleterious modification of environment. The modification may actually or potentially influence human life, living condition, cultural assets or the life cycles of the indigenous plant and animal communities that inhibit a given system. The environmental pollution takes place through changes in energy patterns, radiation levels, physical and chemical constitutions and abundance of organisms. Environmental pollution is closely associated with human problems such as maintenance of renewable sources, geological hazards i.e. earthquakes, landslides, floods etc., indiscriminate consumption of fertilizes, pesticides in agriculture and other natural pollution hazards.

The people inhabiting the watershed often pollute the water in the rivers. The water carries bacteria, some of which are pathogenic and can cause water borne diseases such as typhoid, dysentery, cholera etc. Wastes from some of the industries are let off into rivers and pollute the water rendering it unsafe for human consumption. Surface run off due to rainfall partly percolate into the ground dissolving the salts and minerals present in the soil. As a result, sometimes the groundwater causes diseases such as flourosis due to the presence of fluorides in the water.

Industrialization is generally believed to be the universal remedy for economic backwardness. Mounting pressure on industrialization to with stand in the context of advancement towards economic stability is constantly degrading the environment through air, water and soil pollution. Traditionally industrial solid wastes were used as landfills, the liquid wastes discharged into the sea, river or lagoons and the gaseous wastes let into the atmosphere. In addition to this, a small fraction of the wastes, were also burnt in open. The ambient air and water over an industrial area is a complex mixture of gases, liquids and solids. It may consist of many toxic elements, which may be hazardous, not only to human beings but also to the vegetation in the surrounding area.

Due to the downward and lateral movement of water through hydrological cycle linked up with the underground water recharging, the well waters upto a distance of 500 mts from the river become polluted with the constituents of the effluents. Because of the subsurface contamination can eventually lead to surface water pollution also. As more water is extracted from surface and underground sources to satisfy increasing water demands, more polluted water is returned which may contaminate those sources.

Agra is one of the most industrialized cities of U.P. situated on the bank of the river Yamuna. There are more than 300 industries, which include leather, dyeing, food, and beverage industries etc. The surface and subsurface water bodies in the study area are continuously being polluted because of unabated industrialization. Untreated or partially treated industrial effluents are the important sources of water pollution.

The problem of water pollution in Agra requires remedial measures in order to check the further degradation of groundwater otherwise the extensive groundwater resources may be damaged beyond replenishment and cannot be used for various purposes. In order to monitor the impact of industrial effluents on the environment, identifying the extent of degradation and evolving possible means of minimizing the impacts, studies on quality of effluent polluted river water and waters of adjoining wells has been done.

1.1 HISTORY OF THE STUDY AREA:

Agra is a grand old city, which is famous in the world for the Taj Mahal, which is one of the Seven Wonders of the World. There are various and conflicting versions regarding the early history of Agra.

Some historians are of the view that the origin of Agrabana in all probability goes back to "Arya Griha" (abode of the Aryans) in the green belt of the Yamuna and the Ganga where the earliest Aryans settled.

Aryans chose this site because it was situated between the 'Doab' – i.e. between the fertile valleys of the holy rivers Ganga & Yamuna. Eventually according to the historian Tabloys Wheeler, 'Arya' and 'Griha' were abbreviated and became 'Agra' and corroborates that Agra was one amongst the five early settlements founded by Aryans. Agrabana is also referred to in the great Hindu Epic, 'Mahabharata'.

Emperor Babar as a base chose this city for the Mughals. Most of his early descendants preferred to stay on and for a century and a quarter. Agra was the new centre for an empire, which matched the brilliance and power of its contemporaries.

1.2 LOCATION AND ACCESSIBILITY OF THE AREA:

The district of Agra is situated in the extreme southwest corner of Uttar Pradesh. It lies between the parallels of 26°44' and 27°25' north latitude, and 77°26' and 78°32' east meridians of longitude. Rajasthan bound it on the west, on the south for some distance also by Rajasthan and thereafter by Madhya Pradesh. The district of Firozabad bound it on the east and by districts Mathura and Etah in north.

Agra metropolitan city is located in western part of the Uttar Pradesh on the right bank of river Yamuna at latitude 27°10'N and longitude 78°05'E. Agra lies 200 km south of Delhi on the level and fertile Gangetic plain, which is furrowed by several rivers, the most important of which is the Yamuna. Agra is situated on west bank of Yamuna above 165 m M.S.L. and covers about 65 sq. kms. area. The total population of the city is estimated to be 19,55,694 (Census, 2001).

Falling under tropical area, the winter season is generally very cold and the summer, very hot. Four months, from mid June to September, form the rainy season, when about 85 to 90 percent of the annual precipitation is received. October to February form the winter and March to May are the hot summer months.

Agra city experiences dry climatic conditions except during monsoon. The climate is that of tropical monsoon and it enjoys an invigorating climate. The summers are bright and sunny, but hot and dry, with temperatures ranging between 32°C and 44°C. In winter, the temperature ranges from 7.5°C to 10.5°C. The relative humidity is generally high in the region during rainy season. The driest part of the year is summer.

The general direction of the natural drainage system in the region is toward river Yamuna, which enters the area from the North and followed by meandering courses, passes out of the area in the SSE direction.

Geomorphologically the area is divided in to three units; present flood plain, old flood plain and upland of marginal alluvium. The main source of ground water recharge in the area is rainfall. Larger part of the rainfall directly flows to the stream and its carried away as surface runoff because of increasing impervious strata due to urbanization, a part of it infiltrates to the soil at open ground and reaches to the zones of saturation. Groundwater is the main source of drinking water supply in the study area. Industries have their own tubewells beside this there are large number of hand pumps in different parts of the study area.

1.3 PREVIOUS WORK:

Taylor (1935) carried out statistical analysis of the rainfall in the parts of the Ganga basin.

Anden (1936) conducted experiments and submitted technical reports related to groundwater occurrence in Gangetic Alluvial Tract.

The scientists from the CGWB (Mathura 1958, Shah 1960, and Pathak 1961) carried out groundwater investigations and evaluation of the resource potential in parts of Yamuna basin.

A.M. Khan & N. Nigam (1986) worked on geology and geomorphology of the sub-basin and reported that the basin is probably carved out of Vindhyan basement floor.

R.P. Singh, B.S. Chauhan, Devendra Swaroop and Y.S. Yadav (1999) worked on groundwater quality of Agra city.

A. Saxena, S. Sharma, U.C. Kulshrestha and S.S. Srivastava (1991, env. poll. pp. 129-138) conducted the experiments and reported about the factors affecting the nature of rainwater in Agra.

1.4 AIMS AND OBJECTIVES:

The world famous historical city of Agra is situated on the right bank of the river Yamuna and represented by present flood plain and old flood plain with upland marginal alluvium. Hydrogeology of the city is very complex due to dominance of saline aquifers and sporadic occurrence of fresh water bearing zones. The urban sprawl has affected the hydrogeological regime in number of age. The rapid increase in population has caused heavy withdrawal of groundwater, which resulted in declining of water table in the city. The progressive growth of building construction on the surface has increased the impervious strata, which causes less infiltration and runoff through drains and sewers. The sewers and drains deteriorate the water quality and pollute the groundwater. The growth in demand of groundwater accelerates as standard of living is raised. This compounds the problem to search and develop adequate and sustainable water resources for domestic uses.

1.5 METHODOLOGY:

The following methodology has been adapted to carryout this work:

(1) Preliminary study of available literature of the subject related to the area specially hydrogeology, geology and groundwater pollution.

(2) To carryout the demarcation and mapping of the area including surface and sub-surface water bodies.

(3) Collection of water samples from sub-surface water bodies.

(4) Chemical analysis of water for major ions and trace elements.

(5) Measurement of depth to water level during premonsoon and postmonsoon period.

(6) Assessment of water pollution and its impact on human health.

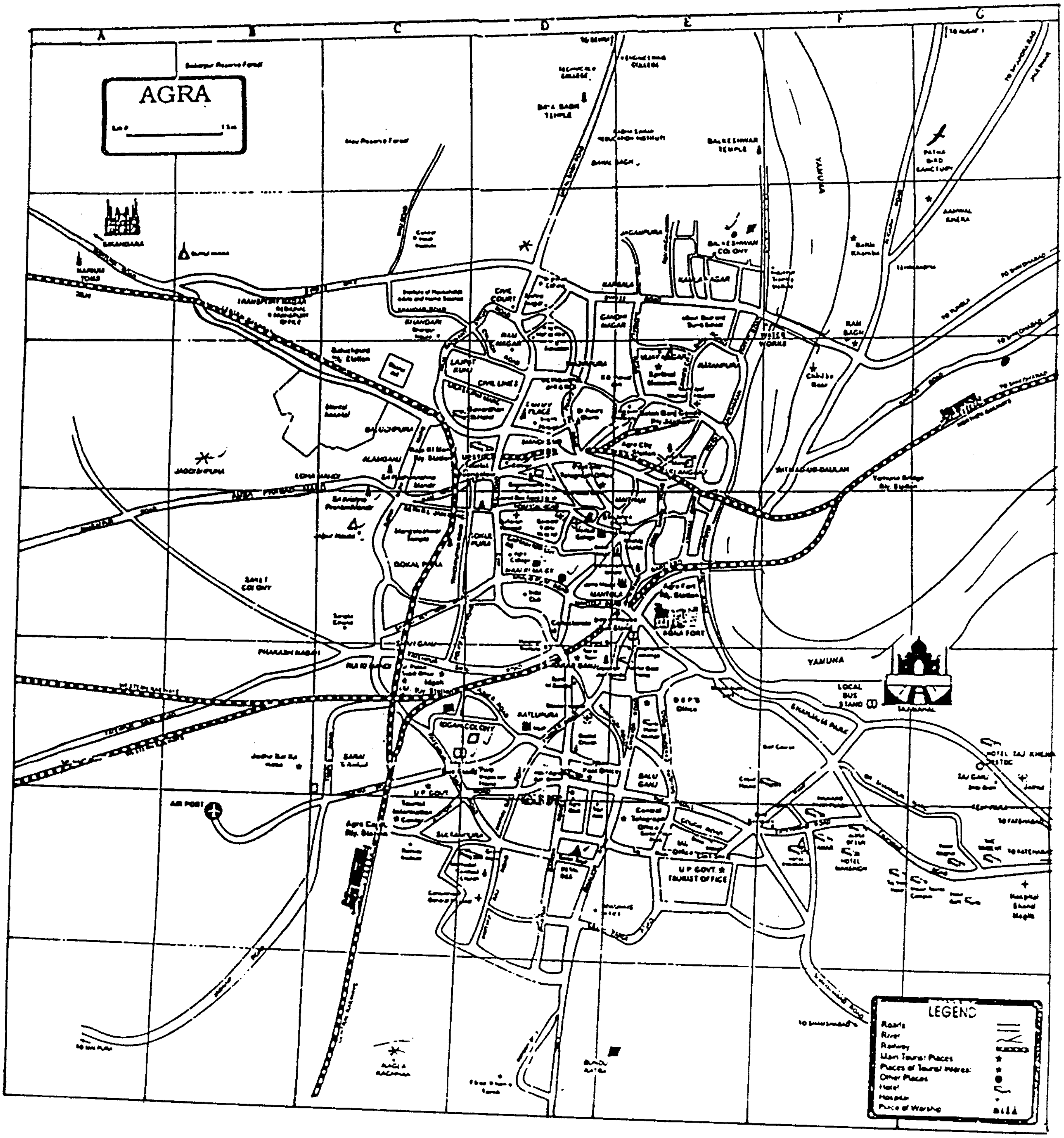


Fig.1.1: Urban map of the study area

Chapter-2

Geology

GEOLOGY

Different meta-sedimentary, sedimentary rocks and Quaternary Alluvium form the geological framework of the district Agra. These formations belong to Bhilwara Super Group, Delhi Super Group, Vindhyan Super Group and Quaternary Alluvium. Vindhyan Super Group is dominating exposed and overlain by Quaternary Alluvium comprising admixture of gravel sand silt and *kankar* in varying proportion. The study area is occupied by the alluvium and wind blown sands. The geological sequence represented in the district is given in the Table 2.2.

2.1 QUATERNARY ALLUVIUM:

The study area forms a part of Yamuna plain of Quaternary age. The alluvium has been derived from the Himalayan ranges and the Bundelkhand highlands by the rivers flowing into the Indo-Gangetic foredeep. The formation is mainly composed of sand, sandy clay, clay with varying amount of *kankar* and is referable to Quaternary period.

The Older alluvium generally occupies a large part of the area away from Recent Flood Plain of Yamuna, the Newer Alluvium occupy low-lying areas within the Older Alluvium. However, the lithological characters of Older Alluvium and Newer Alluvium are more or less similar. The Recent

Flood Plain deposits are designated as Recent Yamuna Alluvial Formation and it is developed along the narrow flood plain of the river.

The Quaternary sediments have been overlain by the Aeolian Cover of the sand sheet, which represents the eastern margin of the arid frontier between Agra and Bharatpur.

The Quaternary cover sediments of the area are referable to Older Alluvial Formation, Newer Alluvial Formation, Recent Yamuna Alluvial Formation and Aeolian Cover. The geomorphology of the area, exhibit positive correlation with lithological formations. Generalized sequence of Quaternary Alluvium has been given in Table No. 2.1.

Older Alluvial Formation:

A yellow and gray clay, silt clay, loam and silty loams occurring above 165 m (M.S.L.) contour constituting a vast Alluvial Plain, whose monotomy has been punctuated by cut off meanders and paleochannels. This layered sequence has been designated as Older Alluvial Formation.

The Older Alluvial Formation occurs as Fills in the vast Indo-Gangetic foredeep separating the newly risen Himalaya from the Archean basement of Bundelkhand. The sedimentation was controlled by the two-watershed originating from the Bundelkhand uplands in South and the tectonic lands of the newly risen Himalaya. The sediments supply from the two petrological provinces of Archean and Tertiary periods is reflected in the subsurface geology of the Indo-Gangetic Fills.

Newer Alluvial Formation:

The sediments comprising brownish yellow silt and gray micaceous sand occurring as channel fills of the D_1 drainage system and low lying areas in the Yamuna basin represents the Newer Alluvial Formation. These occur as outliers within the Older Alluvial Formation, occurring at higher elevation that the Recent Flood Plain deposits of the Yamuna river and present day channel deposits. In the field, the Newer Alluvial Formation is recognized on the basis of its spatial association with low-lying areas in the topographic landscape.

Newer Alluvial Fills of Yamuna valley occur as isolated outcrops showing highly irregular contacts and outcrop distribution.

The facies between the D_1 channel and Newer Alluvial Fills represent period of breaks and possibly non-depositional unconformity of the nature of washout. The river cuts suggest a cyclic sequence of brownish yellow silt and gray micaceous sand, which constitute Newer Alluvial Fills. The Newer Alluvial Formation occurs as Alluvial Fills in the area few meters above the Recent Yamuna Flood Plain. The Newer Alluvial Fills are geomorphologically associated with the D_2 drainage system in the Yamuna valley.

Recent Yamuna Alluvial Formation:

The micaceous gray sand, silt and clay occurring just above the river channel constitute, Recent Yamuna Alluvial Formation deposited along the Recent Flood Plain of Yamuna river. The sediments deposited as point bars, channel bars, and terrace deposits have been designated as Recent Yamuna Alluvial Formation.

The lithounits constituting the formation are developed along the river channels, *nalas*, and the Recent Yamuna Flood Plain. These deposits rest over Newer Alluvial Formation and Older Alluvial Formation in different stretches of Yamuna valley. The Yamuna is an entrenched river cutting through earlier formations (Older Alluvial Formation and Newer Alluvial Formation). The early phase of the Yamuna Flood Plain represents erosional geomorphology. The neotectonism along the Faizabad -Kanpur crustal grain expressed as geophysical lineament, resulted in the local obstruction to the channel development. This initiated development of compressed meanders and accompanying sedimentation of the Recent Yamuna Alluvial Formation.

Aeolian Cover:

West of Agra a vast expanse of Aeolian silicic clastic has been deposited which extend upto Fatehpur Sikri.

The dominant size of the Aeolian clastic varies from fine to very fine sand, the particle size is moderately well sorted and skewness is extremely leptokurtic.

The relief is irregular and the sand covers have been given rise to flat structures landscape in conformity with the subsurface landscape of the Older Alluvial Plain. Locally in the neighbourhood of structural hills and buried pediments, the Aeolian Sand Cover deposits exhibit undulatory surface.

Table 2.1. Geological sequence of Quaternary Cover Sediments.

	Geological Formation	Lithology	Geomorphic Units
Quaternary Alluvium	Aeolian Cover	Sands, *Kankar*	Sand bodies
	Recent Yamuna Alluvial Formation	Micaceous gray sands	Point bar, Channel bar, Flood plain
	Newer Alluvial Formation	A cyclic sequence of brownish yellow silt and gray micaceous sand	Paleochannels
	Older Alluvial Formation	Gray, yellow/brown clay/silt clay loam/ silt loams	Cut off meanders, paleochannels

2.2 VINDHYAN SUPER GROUP:

Mallet (1869) made regional study of the Vindhyan rocks in North Western and Central Provinces of India. He divided the entire Vindhyan succession into two sub-divisions namely Lower and Upper, the former group comprising Semri and sub-Kaimur series of Medlicott (1859) and the latter including the "Kaimur," "Rewah" and "Bhander" sub-groups proposed by Oldham (1859). The study area lies on long line of hills forming the north edge of the Vindhyan plateau extends from Fatehpur Sikri to South Western direction through Rimtumbour near Chittorgarh. The authentic geological work is of Heron (1922), who mapped, the area on the one-inch to one-mile scale. The classification of Vindhyan Super Group is given in the Table 2.3.

The area forms the northerly extension of great Vindhyan basin and represents small part of long belts of Upper Bhander Sandstone Formation. The Upper Bhander Sandstone occurs in the parallel ridges. There are two main ridges. However, the two ridges show opposite direction of dips. The amount of dip ranges between 3^{o} to 35^{o}.

Bhander Group:

In Vindhyan Super Group, the Bhander group is mainly exposed and overlain by Quaternary Alluvium comprising admixture of gravel, sand, silt and *kankar*. Different stratigraphic sections of this groups, were measured and studied along with lithology and internal sedimentary structure.

Table 2.2. Geological sequence of the area.

Age	Super Group	Group	Formation
Quaternary			Recent to sub-recent dune sand, soil and alluvium.
	..............................Unconformity..............................		
		Bhander Group	Sandstone, shale and limestone
	Vindhyan Super Group	Rewah Group	Sandstone and shales
		Kaimor Group	Sandstone and shales
	..............................Unconformity..............................		
Proterozoic			
		Semri Group	Sandstone, shales, limestones, conglomerate and quartzite
		Ajabgarh Group	Argillaceous, meta-sediments, phyllite schists and marble
	Delhi Super Group		
		Alwar Group	Archeans, metasediments consisting of quartzites, phyllites etc.
	..............................Unconformity..............................		
Archean	Bhilwara Super Group	Ranthembor Group	Schists, gneisses and granites.

The Upper Bhander Sandstone occurs in two parallel ridges and shows frequent intercalations of shales. The shaly intercalations are common and occur by and large. The Upper Bhander Sandstone is usually dark red in color with small white spots and pale pinkish passing in some beds into an almost white rock without red staining. Sandstone is hard and compact and the thickness of the individual bed ranges between 3 cm to 1.5 meter.

2.3 SUBSURFACE GEOLOGY OF THE STUDY AREA:

The entire study area has a blanket of thick clay bed, which is underlain by sand formation. This granular zone is encountered at variable depth from 12.19 m bgl to 36.58 m bgl. The thickness of granular zone varies from 4.57 m to 43.30 m. However, it is disposed of in the depth span of 9.14 m bgl to 73.15 m bgl at Agra Mandi Parishad on left bank of Yamuna river. The granular zone encountered has intercalated clay layers in it. In the central part of Agra city around Sanjay Palace, Rakabganj and Shahganj area, the thickness of granular horizon increases maximum to the depth of 70 m. The lithologs of Swamibagh and Agra Mandi Parishad clearly indicate the back swamp deposits, where thin layers of sand and clay deposits have been encountered. The Sanjay Palace, Rakabganj and Tajganj

Table 2.3. Classification of the Vindhyan Super Group

	Groups	Formation	Thickness (in meters)
Upper Vindhyans	Bhander Group	Upper Bhander sandstone Sirbu shales Lower Bhander sandstone Bhander limestone Ganurgarh shales	1000
	Rewah Group	Upper Rewah sandstone Jhiri shales Lower Rewah sandstone Panna shales	2000
	Kaimur Group	Upper Kaimur sandstone Bijagarh shales Lower Kaimur sandstone	400
	......................Unconformity......................		
Lower Vindhyans	Semri Group	**Rohtas Formation:** Suket shales Nimbahara limestone and shale conglomerate and sandstone **Kheinjua Formation:** Glauconite member Fawn limestone Olive shales **Porcellinite Formation:** Porcellinite shales Trappoid beds Porcellinic shales **Basal Formation:** Kajrahat limestone Bleaching shales Basal quartzites and conglomerate	1300

areas show levee deposits, where thick sand layers are encountered in the boreholes. However, the entire physiographic and to some extent the sub-surface character of alluvium is obliterated vis-à-vis modified due to urbanization stress.

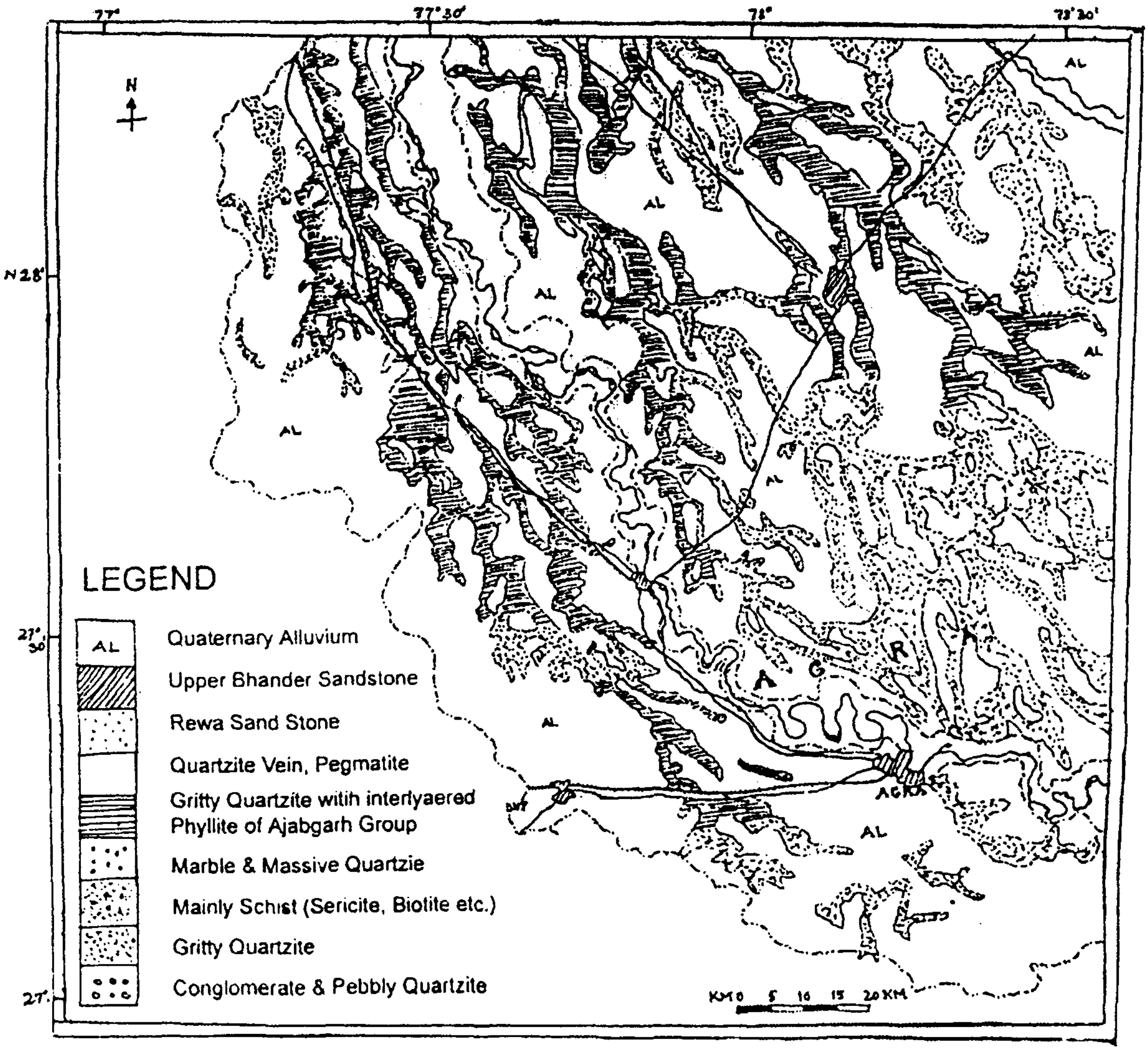


Fig. 2.1: Geological map of Agra and adjoining areas (Interpretation from LANDSAT TM FCC)

Chapter-3

Geomorphology and Drainage

GEOMORPHOLOGY AND DRAINAGE

The Geomorphological studies in the Yamuna sub-basin have been carried out in order to understand the neotectonic of the Yamuna valley. Historically Yamuna has been part of Luni drainage system contributing to the western drainage of the Indian shield. During the last 3000-5000 years (Mahabharat time) the Yamuna underwent drastic change in the drainage; it has become part of the Ganges drainage system. The change in response to the neotectonics has been a major event, which altered the environmental dynamic of the western India changing the catchment of Luni System from Himalayan to Aravalli watershed. The environmental changes were perhaps responsible for the subsequent socio-economic and demographic landscape of India.

3.1 GEOMORPHOLOGICAL SURFACE:

The area under study exhibits four surfaces, which occur as discontinuities in the landscape evolution of the area. In the ascending order of the antiquity the sequence has been presented as:

4 Aeolian cover

3 Recent Yamuna Flood Plain

2 Newer Alluvial Fills

1 Older Alluvial Plain

The above four surfaces have already been described in the previous chapter. Gemorphologically, the present study area can be classified into three main units, Present Flood Plain, Old Flood Plain and Upland of marginal alluvium. Each unit is again demarcated into river channel (RC), sand bar (SB), abandoned channel (AC) and meander scar (MC) in the Present Flood Plain and land with *reh* (S) and without *reh* in Upland marginal alluvium unit. The entire study area is represented by alluvium deposited during Quaternary period. It comprises admixture of gravel, sand, salt, clay, *kankar* in various proportion. The recent deposits are present all along the Yamuna river bank.

3.2 GEOMORPHIC UNITS:

The geomorphic analysis in parts of Agra district has been carried out to establish the relationship between topography and Quaternary geology of the study area. Various geomorphological units have been mapped on the basis of drainage and lithological variation. Geomorphic units were detected and picked up by convergence of evidence from recognition elements. The following units have been mapped from the area.

1. Point bars
2. Channels bars
3. Paleochannels

4. Gullies
5. Structural hills and valleys
6. Hogbacks
7. Erosional hills
8. Rolling plain
9. Sand bodies

1. Point bars:

Point bars are found on the convex side of meanders and grow by individual increament outwards into the meanders carved. The point bars are mostly sandy deposits along the convex margin and occur as ridges within the channel. These are mostly seen along the Yamuna river across it sinuous loops. These are characterized by internal drainage, paucity of biocover, the tapering out lines of the landform and their spatial association within the river channels.

2. Channel bars:

The channel bars are characteristically well developed in the Yamuna river. The channel bars are characterized by the linearity of their trend in homogeneity with the orientation of the river channels.

3. Paleochannels:

The scars of the migratory history of the rivers in the interfluves and flood plain are discernible in the area as paleochannels. These are local depression and have been cutoff from the main drainage system due to depositional barrier across the paleochannels. The paleochannels have been picked up on the basis of their shape, relief characteristics and selective landuse pattern (orchard, plantation etc.). The paleochannels occur as partially filled and filled-up scars, which during floods developed hydraulic continuity with the existing drainage system of the area.

4. Gullies:

Small, linear to curvilinear feature mainly along the bank of river have been interpreted as Gullies. Gullies result from erosion by run off of the precipitation. The initial rivulets enlarge and take on a shape, which are characteristics of material in which the Gullies are carved. Gullies are bad land with negative micro relief.

5. Structural Hills and Valleys:

The pronounced well defined ridges and valleys are seen whose morphotectonics is controlled by structure. The structural hills and valleys have a NNE-SSW trend, which becomes curvilinear due to polyphase deformation of the Delhi Supergorup. The anticlines form structural hills and synclines define complementary structural valleys. Locally the softer lithologies in the anticlinal axial zones have undergone accelerated erosion and have formed the erosional valleys. The ridges features of structural hills have been mapped as hogback slope on the basis of the symmetry of the ridge profile.

6. Hogback:

It exhibits nearly symmetrical ridge profile in the quartzite of Alwar Group. The hogback ridges are covered by thick vegetation. The drainage is external, the first order channels have almost same length of the both side of slopes of the ridge. The hogback topography has been controlled by steeply dipping strata, with high resistance to erosion.

7. Erosional Hills and Valleys:

Isolated landforms projecting abruptly from the alluvium constitute distinct geomorphic features. These erosional features are dependent upon the lithology of the area. Erosional hills have been developed on harder lithology, mostly quartzite as the resistance to erosion is high, while the erosional valleys have been developed on softer lithology. These features can be seen in the area where the rocks of Delhi Supergroup are exposed.

8. Rolling Plain:

The Aeolian tract in the area shows an uneven surface, reflecting the fluctuations of the Aeolian dynamics. The accidented slope of the deposits have given raise to the rolling plain characterized by local variations in the drainage directions, patterns and the types. The landuse is characterized by sparse agricultural activity, human influence is commonly seen as settlements, roads, railway lines etc. The rolling plain has very sharp and pronounced boundaries with the structural hills, but they show gradational contacts with fluvial landform and quaternary deposits. The smoothness of the geomorphic surface is punctuated by the cover of the Aeolian deposits of sand-bodies and the development of surface drainage.

9. Sand Bodies:

The sand bodies are Aeolian features, which have been brought to the area by wind action. These geomorphic features do not show the direction of wind. The sand reflects two distinct i.e. the stabilized or older sand, where as other unit indicate the active and fresh sand bodies. Texturally sand bodies reflect uneven texture and irregular shape and outlines.

3.3 DRAINAGE:

The study area is drained mainly by the Yamuna river. The Yamuna river is one of the most important tributary of the river Ganga. It raises from Yamunotri off Bander-Punch glacier at an elevation of 6330 meters above mean sea level in Tehri Garhwal district of U.P. in the Himalayas. Many small streams like Rishi Ganga, the Uma, the Hanuman Ganga and several others join it in the mountains. The Tons is the longest tributary, which joins Yamuna, below Kalsi. The Yamuna river enters the plain at Tajewala, from it flows due south and joins the Ganga at Allahabad. The velocity of the river Yamuna is about 3 km/hr during normal season and 11 km/hr in the rainy season.

Drainage system:

The area under study has three distinct type of drainage system. They are recognized as D1, D2 and D3 drainage systems, which occur as filled up channel, partially filled channel and channels of present day drainage system respectively.

i) D1 Drainage System:

It is the oldest drainage system in the study area. The paleochannels have been filled up, locally showing meander scars and cutoff meanders. The D1 paleodrainage is defined as low relief areas in the Older Alluvial Plain. Sinuosity and compressed meander zones characterize the drainage.

The D1 channel morphometry has been obliterated by later D2 drainage system, which occurs as superimposed drainage. The D1 drainage system represents a flow regime from southeast to northwest. The regional slope was from Bundelkhand uplands towards the Indo-Gangetic trough.

The D1 drainage system has been picked up as paleochannels with low relief and extensive agricultural activity along the paleochannels. The pattern of the cultivation is arcuate following the channel boundaries of D1, which occurs as meander scars and cutoff meanders. Its association with Older Alluvial Plain recognizes the D1 drainage.

ii) D2 Drainage System:

It is represented by partially filled up channels. The D2 drainage represents rejuvenation of northwesterly drainage, which resulted in the cutting of the scars by the paleochannels. The partially filled up channels at places support extensive agricultural activities. The D2 drainage is characterized by sub-dendretic drainage, basin along with linearity and elongation. The channels have been filled up at places due to changes in the fluvial dynamics. The D2 drainage has characteristics of youthful stage. The paleochannels are marked as depression on the Older Alluvial Plain. They support good cultivation.

iii) D3 Drainage System:

The present day drainage is considered as D3 drainage. The drainage channels are erosional cutting through the Alluvial Formation of Older and Newer Alluvial Plains. The present day D3 channels are shallow and the main Yamuna channel is entrenched. The present day channel shows dendretic to sub-dendretic pattern and negative relief.

Older Alluvial Formation has external drainage with dendretic pattern. Bedding is present in the area where Yamuna has cut through Older Alluvium along its channel. The formational boundaries are irregular, the agricultural fields and human settlements cover the most of the area. The narrow and steep gulley profile suggests fine grain clastic, clay, silt and loam. The scars of D1 drainage system indicate a northerly drainage originating from Bundelkhand uplands into the Indo-Gangetic foredeep.

Newer Alluvial Formation has external drainage with dendretic pattern. The litho unit shows low resistance to erosion, the valley are narrow and steep, the boundaries are irregular in shape. The human influence in the lithounit can be put under upland cultivation.

Recent Yamuna Alluvial Formation has external drainage and lithounit shows low resistance to erosion, the boundaries are irregular. The vegetation and human influence are scanty, the unit is spatially associated with present channel of Yamuna and Recent Yamuna Flood Plain, and it therefore, represents the youngest formation of Yamuna valley.

Aeolian Cover has sparse external drainage; drainage is generally absent in the sand cover. The relief is irregular and the sand covers have been given rise to flat structures landscape in conformity with the subsurface landscape of the Older Alluvial Plain. Locally in the neighbourhood of structural hills and buried pediments, the Aeolian Sand Cover deposits exhibit undulatory surface.

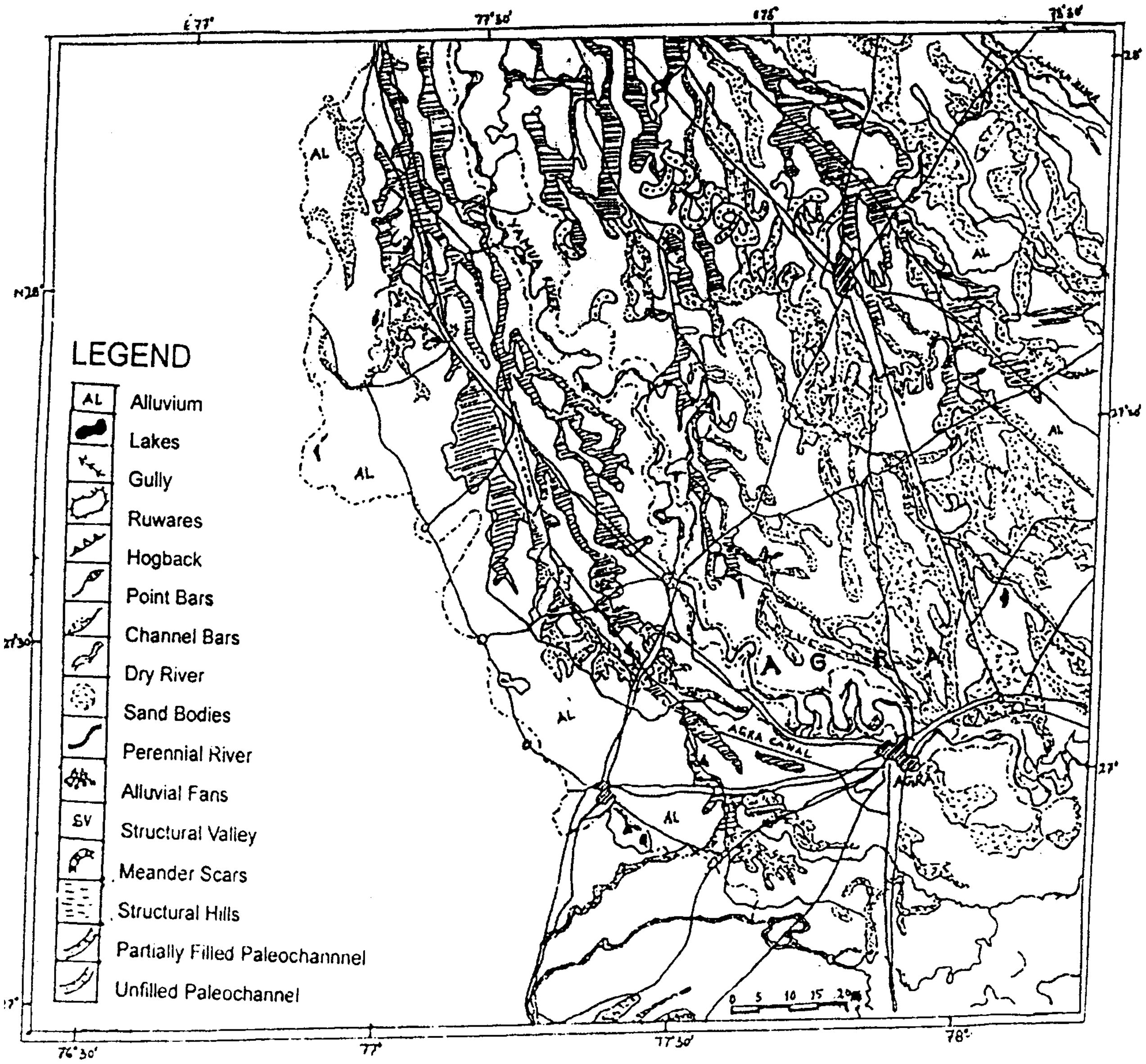


Fig. 3.1: Geomorphological map of Agra and adjoining areas (Interpretation from LANDSAT TM FCC)

Chapter-4

Hydrogeology

HYDROGEOLOGY

Hydrogeology concerned primarily with the mode of occurrence, distribution, movement and chemistry of water occurring in sub-surface in relation to the geological environment. The geological framework broadly governs the occurrence of water in sub-surface. Most of human activities involving industrial and agricultural development, and the adequate management of land and water resources have directly or indirectly resulted in the degradation of hydrogeological environment.

4.1 AVAILABILITY OF GROUNDWATER IN VARIOUS LANDFORMS:

Based on available hydrological informations, a hydrogeomorphological map of the Agra city and its environs has been prepared (Fig. 4.2). The potential characteristic of each landform has been identified, assessed and projected in Table 4.1.

Table 4.1 indicates that fresh water availability is localized along Yamuna river and its proximity down to the maximum depth of 55m. However, this depth span gradually decreases towards upland marginal alluvium where fresh water occurs only in isolated patches. Precise demarcations of these saturated fresh pockets or patches are only possible through geophysical resistivity surveys.

Table 4.1: Groundwater potential of different landforms (S. Mukherjee and J.N. Rai, CGWB, 1996)

Landform	Nature	Water potentiality
River channel	Discharge zone	Good, down to depth of 55 m and underlain by saline water. Discharge: more than 15 lps.
Sand bar	Discharge zone	Good, down to depth of 55 m and underlain by saline water. Discharge: more than 15 lps.
Abandoned channel	Discharge zone	Good, down to depth of 55 m and underlain by saline water. Discharge: more than 15 lps.
Meander scar	Discharge zone	Good, fresh water down to depth of 55 m bgl.
Younger terrace	Recharge and discharge zone	Good, fresh water down to depth range of 30 to 45 m. Discharge: 1 to 15 lps.
Older terrace	Recharge and discharge zone	Good, fresh water down to depth range of 30 to 45 m. Discharge: 1 to 15 lps.
Upland marginal	Recharge zone	Moderate to good. Fresh water occurs only in patches down to 30 m bgl. Discharge: 1 to 15 lps.

4.2 OCCURRENCE OF GROUNDWATER:

The district Agra is covered by both central and marginal alluvium and the hard rock belonging to the Proterozoic age. The basement comprised of formations belonging to Vindhyan system. Groundwater in the study area occurs both under confined and unconfined conditions. The general direction of groundwater flow is from NNW to SSE. The river

Yamuna has been established to be effluent in nature. Depth to water level varies widely. An appraisal of various lithological logs indicates that medium to fine sand with *kankar* forms the principal aquifer in the study area.

According to U.P. Jal Nigam, Agra (2004), aquifer performing tests concluded on selected hand pumps show that saturated aquifer have yielded 13 liter/minute to 15 liter/minute and the water level stables at 13 m to 21 m in 2004, which was 14 liter/minute to 16 liter/minute and 12 m to 18.50 m respectively in 2001. It shows a decreasing trend in water level.

The study area is a part of Ganga-Yamuna interfluves. The deposition of alluvial sediments probably took place under tropical climate with semi-arid conditions. The presence of large nodules of *kankar* at varying depths associated with hard yellow and reddish clay suggests possible periods of sub-aerial exposures above the Yamuna river system under semi-arid to sub-humid tropical climate and shallow groundwater conditions. The thick of sediments comprising sands of various grades, silt and clay intercalated with *kankar*, various sand bodies forms the prolific aquifer. Rainfall forms the principal source of groundwater recharge in the study area. Larger part of the rainfall directly flows to the streams and is carried away as surface run-off, a part of it infiltrates to the soil at open grounds and reaches to the dynamic zones of saturation. Besides the surface recharge in the form of irrigation return flow and numerous surface bodies like ponds and lakes in the area also contribute to the groundwater bodies through vertical seepage.

4.3 MOVEMENT OF GROUNDWATER:

The groundwater movement is governed by established hydraulic principles (Todd, 1959). Groundwater moves in the direction of slope of water table. The slope of water table in turn depends upon many factors such as permeability and thickness of water bearing zone, the topography, lithology and local variations in the quantity of recharge and discharge (Hubbert and Toth, 1962). The general groundwater flow in consonance with the regional groundwater flow direction in the central Ganga basin is from NE-SE direction.

Groundwater movement follows the surface topography and it is from west to east on right bank and from east to west on the left bank of Yamuna river. The Yamuna river appears to be effluent in nature except in monsoon period when it forms bank storage. However, there are some local variation in groundwater movement due to local changes in form and slope of topography. Hydraulic gradient is also different in the left and right bank due to variation in ground slopes and other related governing factors.

4.4 DEPTH TO WATER LEVEL:

The water level in an unconfined aquifer is the upper surface of the zone of saturation where the pressure is atmospheric. It is defined by the level at which water stands in wells penetrating the aquifer, just enough to hold standing water. In general the water level standing in dug wells are considered accurate enough to represent water level of an area.

In premonsoon (May-2004), the depth of water table ranges from 10.5 m to 23.5 meters below ground level. The deeper levels were recorded as 23.5 meters and shallowest water level as 10.5 meters was recorded below ground level.

In postmonsoon (Nov.-2004), the depth to water table ranges from 9.0 meters to 21.3 meters below ground level. The deeper levels were recorded as 21.3 meters and shallowest level was observed as 9.0 meters.

Water table in the phreatic zone fluctuates in response to:

- Rainfall incidence at Agra city and its environments
- Form and slope of the ground level and built up area
- Recharge to groundwater from surface water source, i.e., Yamuna river and Agra canal
- Loss due to evapotranspiration
- Draft from groundwater development structures, i.e. tube wells, hand-pumps, wells, etc

- Inflow and outflow from groundwater regime.

4.5 WATER LEVEL FLUCTUATION:

The groundwater level fluctuation is a function of time and space in response to precipitation. The changes in water levels are due to the change in storage of groundwater in an area. It can also be caused due to excessive withdrawal of water from aquifer than the quantum of average annual recharge. The difference in groundwater level shows a seasonal pattern of fluctuations. This results from influence such as rainfall and irrigation pumping that follows well-defined seasonal cycles. In the study area the groundwater fluctuation has been observed and it ranges from 0.5 m to 5.5 m in the year 2004.

4.6 AQUIFER POTENTIALITY:

The study area has a battery of hand pumps, which tap the top shallow aquifer within the depth span of 55 m bgl. The structures are mostly constructed by individual as also by Uttar Pradesh Jal Nigam to cater the domestic requirements. The groundwater levels in these structures vary from 4.56 m bgl at Mandi Parishad (left bank of Yamuna) to as much as 15.85 m bgl at Hydel sub-station, Sikandra. The well structures can sustain very limited discharge, which varies from 13 to 15 lpm at fairly high drawdown component (3.96 m to 9.15 m) depending upon location-specific condition.

Table 4.2: Water level fluctuation data and depth to water level below ground level during premonsoon and postmonsoon periods, 2004

Sl. No.	Locations	Depth to water level below ground level (m)		Fluctuation (m)
		Premonsoon	Postmonsoon	
1.	Lajpat Kunj	19.00	15.00	4.00
2.	Bharatpur House	18.50	16.00	2.50
3.	Chipitola	17.50	13.00	4.50
4.	Kazipada	16.00	14.50	1.50
5.	Mamu Bhanja Ghatia	21.00	15.50	5.50
6.	Mantola Thana	20.10	16.50	3.60
7.	Charbagh	13.00	10.00	3.00
8.	Sorokatra	12.50	9.00	3.50
9.	Teela Mattamal	23.00	21.00	2.00
10.	Purani Mandi	23.60	21.30	2.30
11.	Hanuman Chauraha	18.00	15.10	2.90
12.	Kotla House	17.80	16.10	1.70
13.	Swami Bagh	17.00	15.10	1.90
14.	Dayal Bagh	17.60	15.30	2.30
15.	Nunhai Chauraha	11.00	9.50	1.50
16.	Trans-Yamuna Colony	10.50	10.00	0.50
17.	Naubasta	18.00	16.00	2.00
18.	Telipada	18.70	16.20	2.50
19.	Idgah Bus Stand	14.15	11.00	3.15
20.	M.S. Colony	13.61	10.20	3.41
21.	Samjay Place	18.00	14.00	4.00

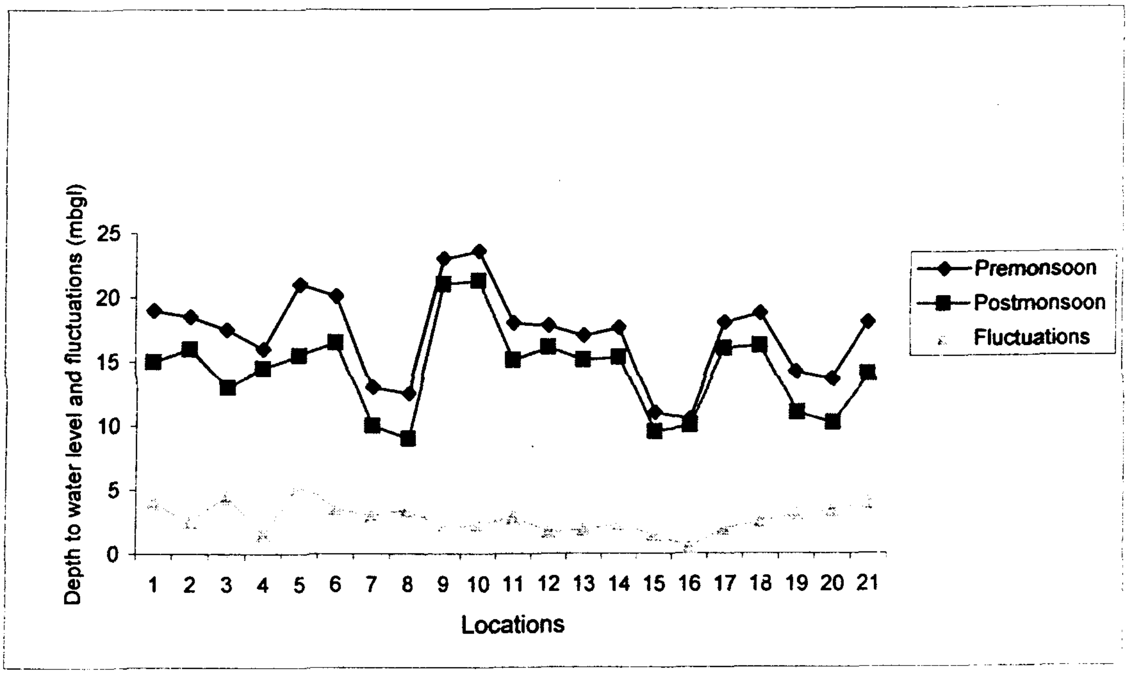


Fig. 4.1: Line graph showing water level fluctuations and depth to water level below ground level (m) during premonsoon and postmonsoon periods, 2004

Locations

1	Lajpat Kunj	12	Kotla House
2	Bharatpur House	13	Swami Bagh
3	Chipitola	14	Dayal Bagh
4	Kazipada	15	Nunhai Chauraha
5	Mamu Bhanja Ghatia	16	Trans-Yamuna Colony
6	Mantola Thana	17	Naubasta
7	Charbagh	18	Telipada
8	Sorokatra	19	Idgah Bus Stand
9	Teela Mattamal	20	M.S. Colony
10	Purani Mandi	21	Samjay Place
11	Hanuman Chauraha		

Tube wells, which are relatively deeper, have encouraging yield prospect, which varies from 100 lpm (at Taj Nagari I) to 1500 lpm (at Sanjay Palace). Drawdown, in fact is highly variable, ranging from 3.16 m (Swamibagh area) to as much as 14.94 m (Rakabganj). Following are the aquifer parameters, computed from Agra Mandi Parishad tube well of GWD.

T	(Transmissivity) m^2/day	23.86
S	(Storativity) m^2/day	1.72×10^{-3}
K	(Hydraulic conductivity) m/day	2.04

4.7 GROUNDWATER RESOURCES AND UTILIZATION:

Groundwater is an important source of water supply throughout the world. Its use in irrigation industries, municipalities and rural homes continues to increase. The utilization of water both surface and subsurface depends upon the groundwater resources of the area. With the establishment of industries and rapid increase in population of the area, there is profound increase in the demand of water supply. The main source of water in the area under investigation is groundwater. The water from Yamuna river in Agra is used for irrigation and industrial purposes.

The area receives rainfall during the southwest monsoon period from July-September. Principal natural recharge includes precipitation and Yamuna river. Artificial recharge occurs from excess irrigation in rural areas, seepage from canals and water purposely applied to augment groundwater supply. Because of high temperature in the area a large amount of water is lost through evaporation.

On account of rapid increase in population and heavy concentration of industrial units in Agra, the effect of inversion of temperature is very pronounced with frequent occurrence of smog in the winter evening and mist in the colder morning hours. Due to suspended pollutants in atmosphere, the rainwater often turns acid and turbid and subsequently causing water pollution in the natural surface drainage system and subsurface water bodies.

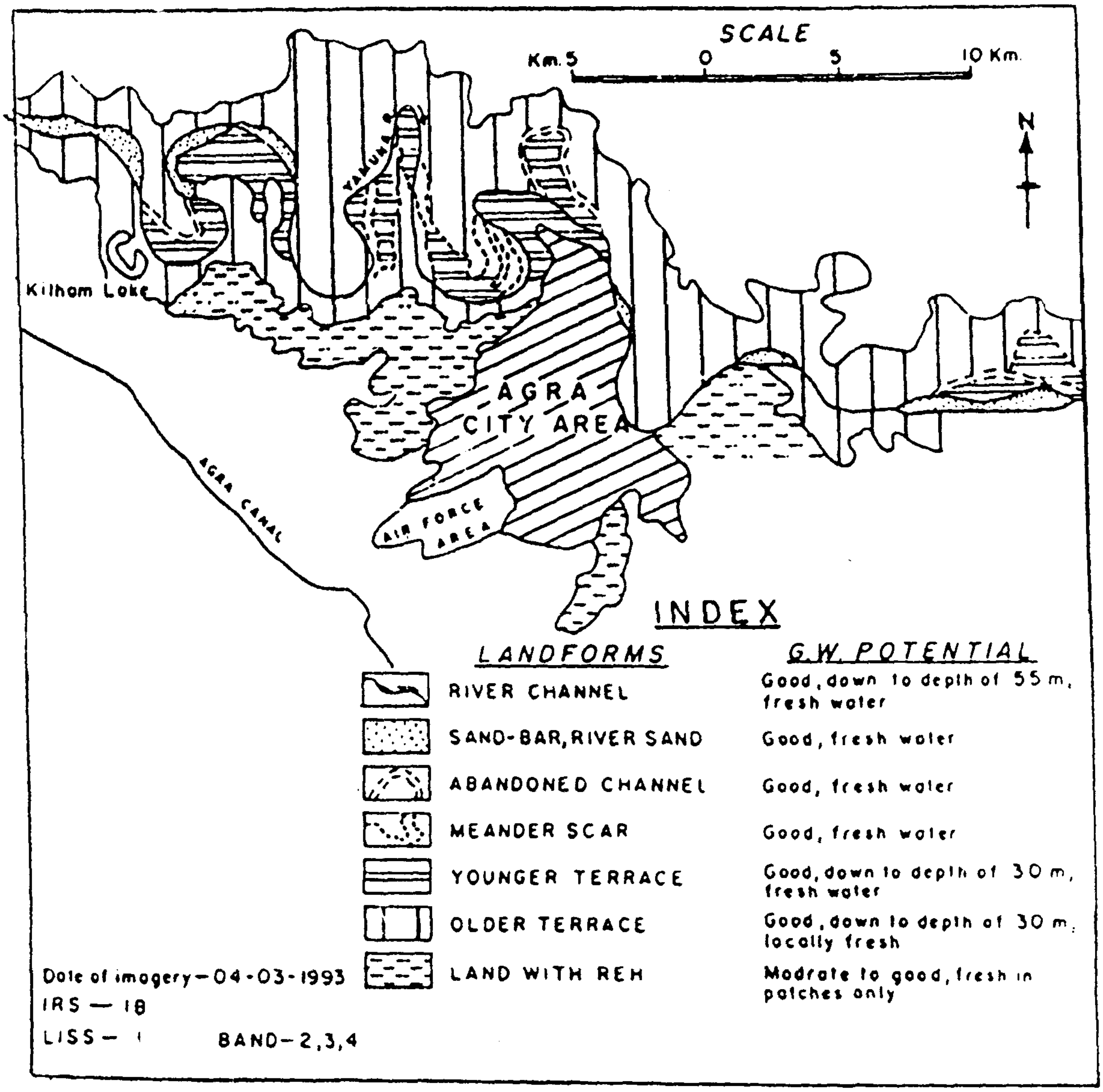


Fig. 4.2: Hydrogeomorphological map of Agra and its environment

Chapter-5

Geoenvironmental appraisal and its impact on groundwater

GEOENVIRONMENTAL APPRAISAL AND ITS IMPACT ON GROUNDWATER

Land and water are very cherished and valuable components of ecosystem, preservation of which is obligatory responsibility of the civilized society for its own survival. It is obvious that large scale uncontrolled exploitation of land and water resources by mining and industrial activities for sustained development is expected to leave deep imprints on geoenvironmental scenario. Such irreparable damage in the long run is likely to endanger the existing ecological balance of interdependency between biotic and abiotic components.

Geoenvironmental appraisal of any region is important for planning its future development and utilizing its natural resources. In order to achieve and assess the environmental profile of the area, it is necessary to study and determine various parameters such as geology, geomorphology, hydrology, soil and landuse. These are of immense use in bringing out a comprehensive picture of the terrain in order to make the best use of available resources without harming the natural ecosystem.

Assessment of natural resources is a prerequisite for perspecting planning in the development activity of an area (Chaudhuri, 1992). Since the terrain conditions play a vital role, its geomorphic characteristics (landform) form the fundamental base for formulating development planning. The geoenvironmental assessment of Agra city is a step in this direction.

Agra is one of the most industrialized cities of Uttar Pradesh, situated on the right bank of the river Yamuna and amongst the densely inhabited regions of the country. The anthropogenic processes including the rapid urbanization and industrialization in and around Agra are responsible for modified landform and landuse pattern. This interference with the geoenvironmental system has resulted in a series of imbalances leading to severe geoenvironmental degradation.

5.1 GEOENVIRONMENTAL PROBLEMS OF THE STUDY AREA:

The geoenvironmental hazards of the study area are mainly associated with the inherent geological and geomorphological setting and exogenic process of land degradation of anthropogenic nature. Major geoenvironmental problems observed in the study area are soil alkalinisation, soil erosion, water logging, floods, river aggradation, groundwater salinity, sand mining and water pollution.

Soil alkalinisation:

The soil alkalinisation is one of the major land degradation hazard affecting large tracts of alluvium of the study area. The problem in the area is primarily related to the upward migration of dissolved salts of mostly sodium sulphate and sodium bicarbonate and found a 3 to 10 cm thick layer on the surface is locally known as *reh*. The concentration of sub-soil salts mainly sodium carbonate, bicarbonates and sulphates with sodium chloride, renders the area barren and infertile. The causative factors for this phenomenon are, humid and dry climate, low gradient of surface, variation in the composition of alluvium, shallow water table condition with capillary zone reaching to the surface level affected by evaporatranspiration process.

Soil erosion:

Due to oscillatory migration of major meander loops of Yamuna river, the bank erosion during rainy season is alarming all along their courses, eating up large chunks of agricultural land every year. In some critical sectors, the bank erosion has reached alarming proportion. With progressive erosion, there are portents of diversion of the Yamuna course itself through a nearby palaeochannel. This possible future eventuality might result in flooding of very large area in this part with catastrophic effects with colossal loss of life and property. This change in geomorphic configuration will also have a very devasting impact on the surrounding ecosystem of the area around Agra.

Water logging:

Water logging of both perennial and seasonal nature are common in low lying depression areas along palaeochannels, *tals*, oxbow lakes, back swamps etc. Water logging is surface water ponding and drainage congestion associated with natural geomorphic depressions of Yamuna Plain, at places also abetted and aggravated by shallowing of water table, also locally artificially induced by the seepage from irrigation canals. These waterlogged areas are not cultivated and are major constraints in their optimal landuse.

Water ponding is also due to lateral seepage of Agra canal and distributaries in the study area. The seasonal water logging is mainly associated with the most of the natural depressions such as oxbow lakes, *tals*, palaeochannels, just after rains. But little of them where water table is very shallow, water ponding is perennial and after rains, the accumulated water overflows the surrounding areas.

Floods:

Floods are one of the most important natural hazards that not only influences landform morphology, but also causes human misery and enormous loss of property. According to CSE report (1985), the most flood prone areas in the country; are in the Ganga & Brahmaputra basin, where the annual flood damage account for about 60% of the total.

Older and Newer Flood Plains of river Yamuna as well as the other major streams and *nalas* are prone to floods in the study area, to varying extents. The floodwater first inundates the Active Flood Plain zones almost entirely and then with increasing intensity causes widespread inundation of lower terraces of Older Flood Plain. Thus flooding of Active Flood Plain and lower terraces of Older Flood Plain is, in general, a recurring feature. The higher level of erosional terraces all along the course of Yamuna is generally inundated only during periodic flash floods of very high intensity. During high floods, due to back flow of water some low lying areas of Yamuna Plain marginal to the rivers are also flooded. The flood prone terrace plains at Poiya Ghat, Swamibagh, Dayal Bagh, Ghatwasan, Tajganj on the right bank of Yamuna and a part of trans-Yamuna area on left bank normally get flooded and recharge the aquifer of the area.

Urbanization is also aggregated flooding due to increased run-off, since infiltration is been less due to black topped roads and covered ground by buildings and other structures. Heavy deforestation in the catchment area and modification of channel configuration by population pressure, the riverbed has been considerably raised by siltation, rendering it unable to cope with the abnormal monsoon discharge. This is the main cause behind the flood havoc in the area.

River Aggradation:

Urbanization is bound to contribute large quantities of sand and other debris. Studies carried out on impacts of urbanization on rivers show accelerated sediments yields, formation of bars and aggradation of rivers (Fox, 1976).

In the southeastern part of the study area, the aggradation is likely to be more acute, due to easy erodability of unconsolidated Quaternary sediments. As per relationship between sediment yield and drainage area for various landuses, the Agra urban area of 65 sq.km. may yield a sediment discharge of about 4 acre ft/year.

Sand Mining:

Sand fine to course grained, grey in color carried by Yamuna river, is being mined at some places. More than 100 million tones of sand is mined per year, that has changed the landuse pattern in the flood plains of Yamuna river and is also responsible for making the area of higher elevation more prone to flooding because of cutting of the levee portion between the Older Alluvial Plain and the Recent Flood Plain for facilitating the truck traffic to the mining site.

Groundwater salinity:

Groundwater though alkaline but it is fit for domestic and irrigational purposes in the study area. The groundwater of the area is saline and has high alkali content that makes the water brackish.

5.2 GROUNDWATER POLLUTION:

Groundwater pollution may be defined as the artificially induced degradation of natural groundwater quality. Pollution can impair the use of water and can create hazards to public health through toxicity or the spread of diseases. Most pollution originates from the disposal of wastewater following the use of water for any of a wide variety of purposes. Thus a large number of sources and causes can modify groundwater quality, ranging from septic tanks to agriculture.

The quality of groundwater is just as important as its quantity. Rainwater is the purest form of water. But as it falls to ground, it collects dust and dissolves certain gases forming acids. When it flows on the surface, it collects decayed vegetable matter, which forms organic acids in water. Also when it percolates into the soil, certain salts and minerals get dissolved in it.

Groundwater pollution resulting from land disposal of liquid or solid waste has become serious problem not only in Agra but also in several parts of the country. The possible pollutants in groundwater are virtually limitless. Groundwater pollution is caused by the presence of certain organic, inorganic and radioactive substances in industrial water present in suspended or colloidal form.

Mechanism of groundwater pollution:

The mechanism of groundwater pollution is very much different from that of surface water. The effect of surface water pollution are evident in a short time due to perceptible changes in color, taste, and odor whereas the groundwater pollution may take place several months, years or decades after pollutants are discharged on land.

The important factors that effect movement of pollutants in the saturated zones are dispersion and convection. Apart from density differences causing mixing of pollutants in the aquifers, dispersion also plays an important role in mixing pollutants in the aquifer system. Molecular diffusion results in mixing of two adjacent miscible liquids even if there is no flow. In case of mechanical dispersion, the spreading is caused by velocity variation and is higher than molecular dispersion.

In convection process, the pollutants transfer is by water moving with the same velocity and direction as pollutants. The convection motion of a pollutant depends on the groundwater flow field, which in turn depends on the peizometric head distribution, hydraulic conductivity and boundary conditions.

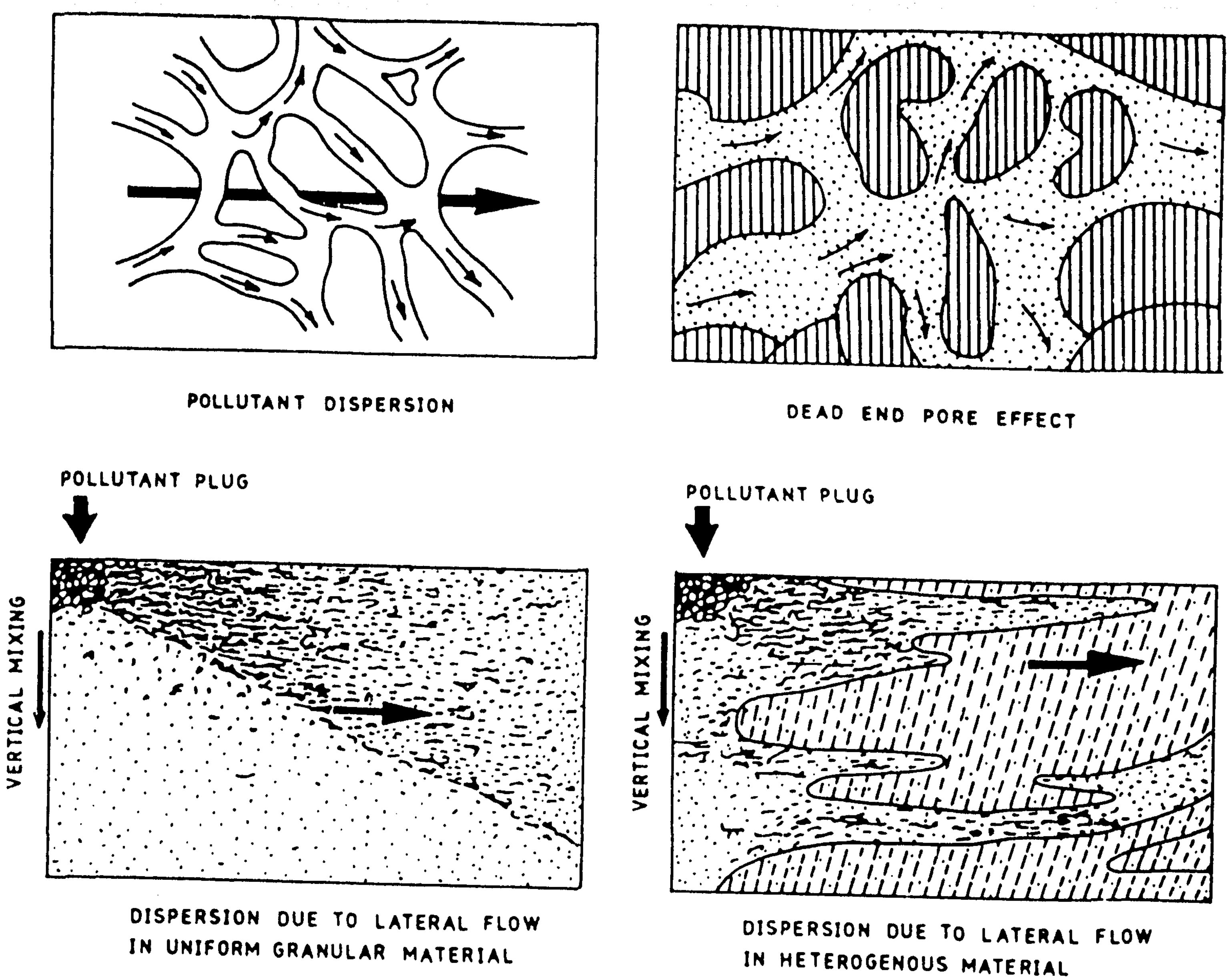


Fig. 5.1: Conceptual dispersion of pollutants in the saturated zone.

Movement of pollutants in the groundwater:

When the pollutants move through the unsaturated zones, they travel primarily vertically downward from the surface and the solute undergoes only a small degree of horizontal placement. In the unsaturated zone, the movements of pollutants is increased by the effect of following factors:

(i) The moisture content of the soil.

(ii) The hydraulic gradient and hydraulic conductivity.

(iii) The relative portion of active pore spaces, which transmit water.

(iv) The climate of the region.

It takes considerable time for solute to percolate through the zone of aeration.

As soon as the pollutant reaches the saturated zone, it usually spreads out laterally and moves in the direction of groundwater flow. The pollutants in the saturated zone either floated on the top of the aquifer at the water table or move into the aquifer if contaminated water is buoyant.

Sources of pollutants:

Every human activity results in the generation of some water pollutants and vary in wide range from activity to activity. The principal sources and causes of groundwater pollution are classified into three categories:

(1) Municipal and domestic sources

(2) Industrial sources

(3) Agricultural sources

(1) Municipal and domestic sources of groundwater pollution:

Municipal sources of groundwater pollution include wastewater from homes and commercial establishments. The domestic wastes in the study area are organic in nature and get oxidized by bacterial decomposition to nitrate, phosphate, carbon dioxide and water. Most of the population of the area is domiciled in buildings connected to sewage-treatment system. After the minimal treatment, these materials are released into the waterways, lakes, and river and are finally reaches to groundwater. Among the municipal sources of pollutants, the common sources are

(a) Solid wastes

(b) Liquid wastes

(c) Sewer leakage

(a) Solid wastes:

The land disposal of solid wastes creates important source of groundwater pollution. Hundreds of tons of garbage and rubbish are thrown in depression or landfill in industrial sites of Agra town. After decomposition, these materials are dissolved and become suspended in

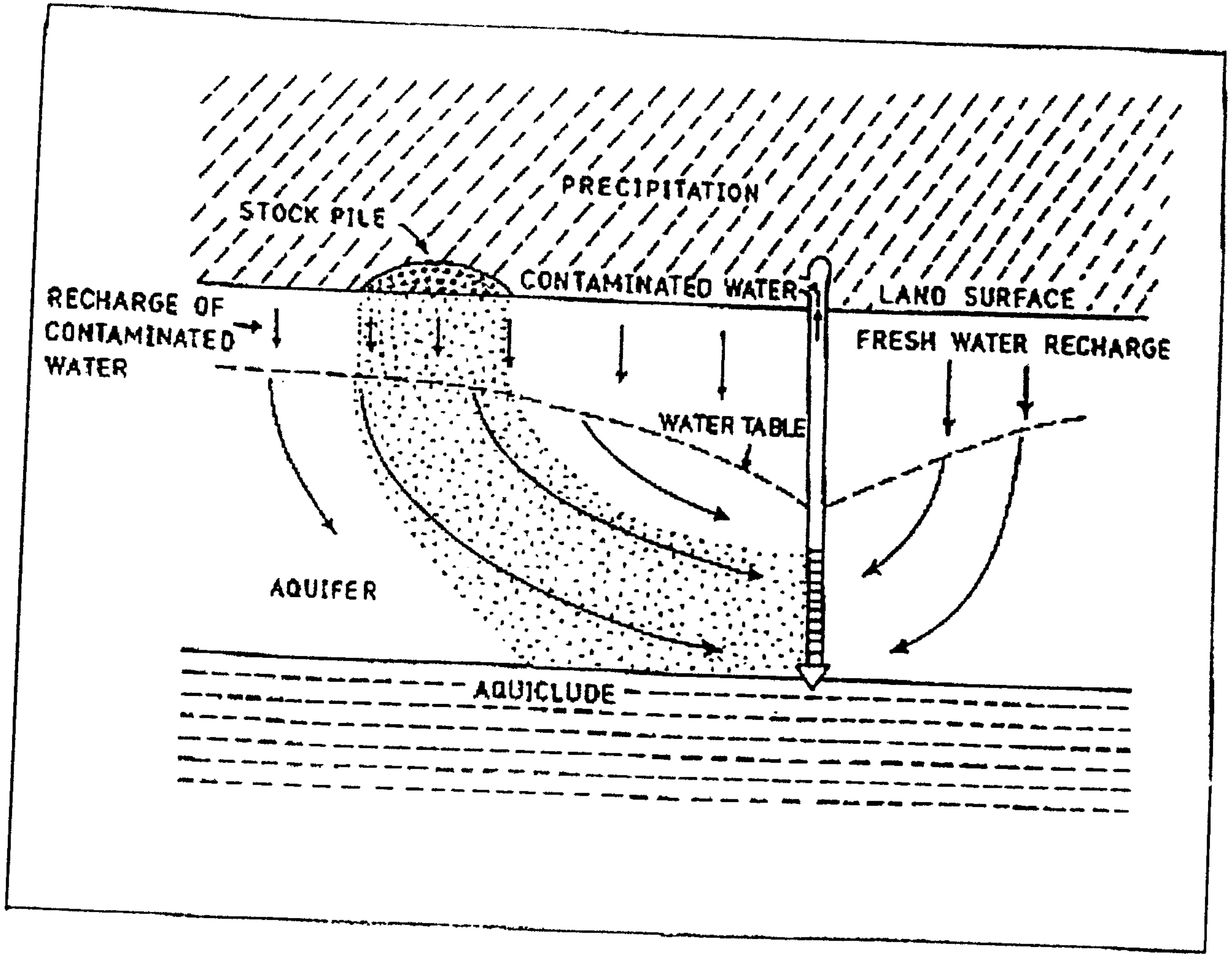


Fig. 5.2: Contamination of an aquifer by leaching of surface soil.

rainwater, percolating into ground, which tends to contaminate not only the groundwater but also surface water. The disposal of solid domestic waste poses many problems depending upon both, the type of waste and disposal method employed. The dissolved material tends to move due to concentration gradient and osmosis. Important pollutants frequently found in leachate of the study area include BOD, COD, Fe, Mn, Cl^-,NO_3^-, hardness and trace elements.

(b) Liquid wastes:

Wastewater in an urban area may originate from domestic uses, industries etc. There is an increasing trend for treated wastewater to be recharged into the ground where it mingles with naturally occurring groundwater and subsequently becomes available for reuse. Municipal wastewater can introduce bacteria, viruses and inorganic or organic chemicals into groundwater. In the study area, the domestic liquid wastes consist of organic pollutants and get oxidized by bacterial decomposition to nitrate, phosphate and carbon dioxide.

(c) Sewer leakage:

The leakage of sewage into the ground is a common occurrence, especially from old sewers. Leakage may occur from poor workmanship,

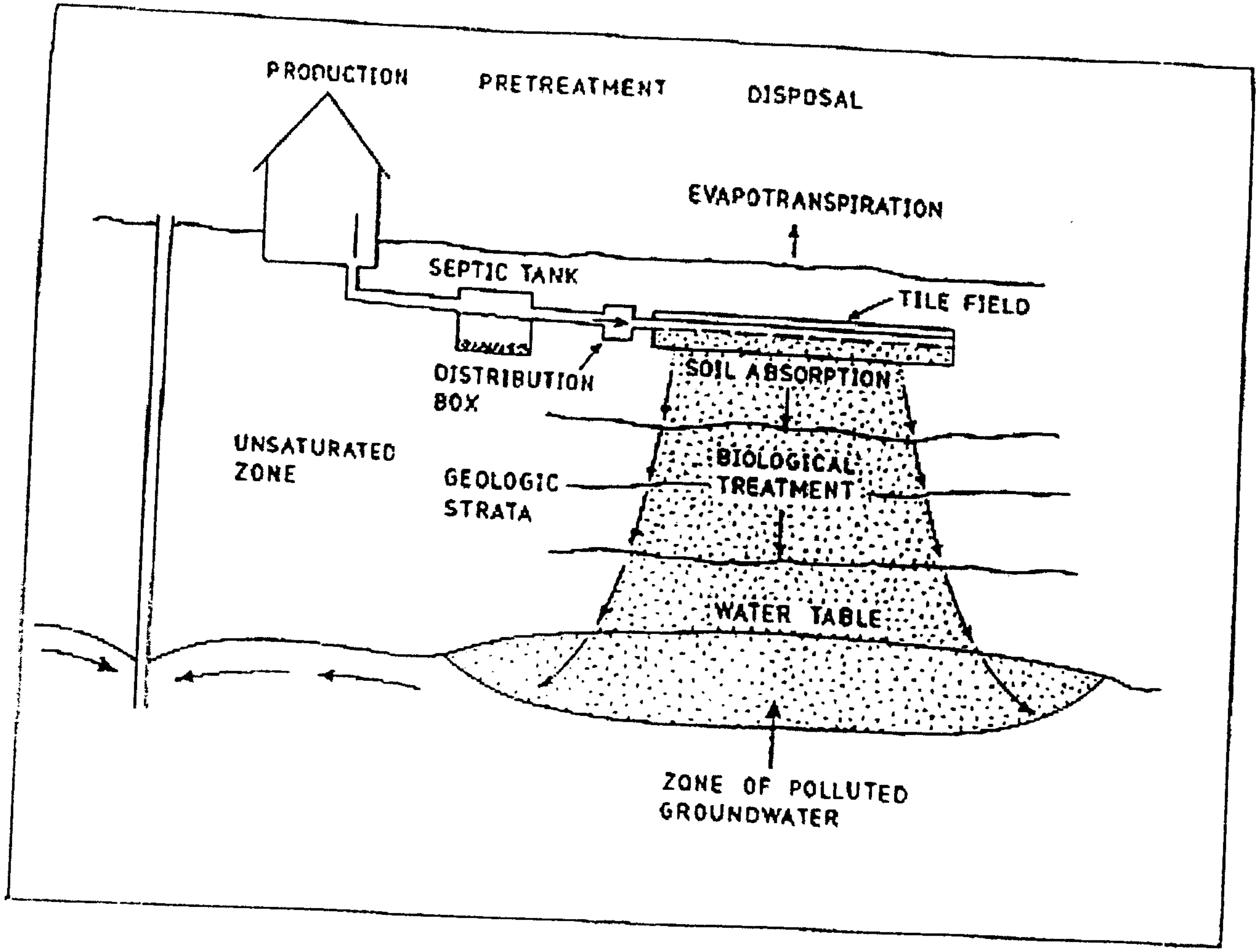


Fig. 5.3: Disposal of household wastes through a conventional septic tank system.

defective sewer pipe, breakage by tree roots, ruptures from heavy loads or soil slippage, fractures from seismic activity, loss of foundation support, shearing due to differential settlement at manholes and infiltration causing sewage flow into abandoned sewer lines. Sewer leakage can introduce high concentrations of BOD, COD, nitrate, organic chemicals and possibly high quantity of bacteria into groundwater of the study area. Where sewers serve industrial areas, heavy metals such as As, Cd, Cr, Cu, Fe, Pb, Mn and Hg may enter in the wastewater.

Table 5.1 Representative ranges of various inorganic constituents in leachate from sanitary landfill (after Griffen et al., 1976).

Parameter	Representative range (mg/L)
K^+	200-1000
Na^+	200-1200
Ca^{2+}	100-300
Mg^{2+}	100-1500
Cl^-	300-3000
SO_4^{2-}	10-1000
Alkalinity	500-10,000
Fe	1-1000
Mn	0.01-100
Cu	<10
Ni	0.01-1
Zn	0.1-100
Pb	< 5
Hg	0.1-10
NO_3^-	10-1000
PO_4	1-100
pH	4-8

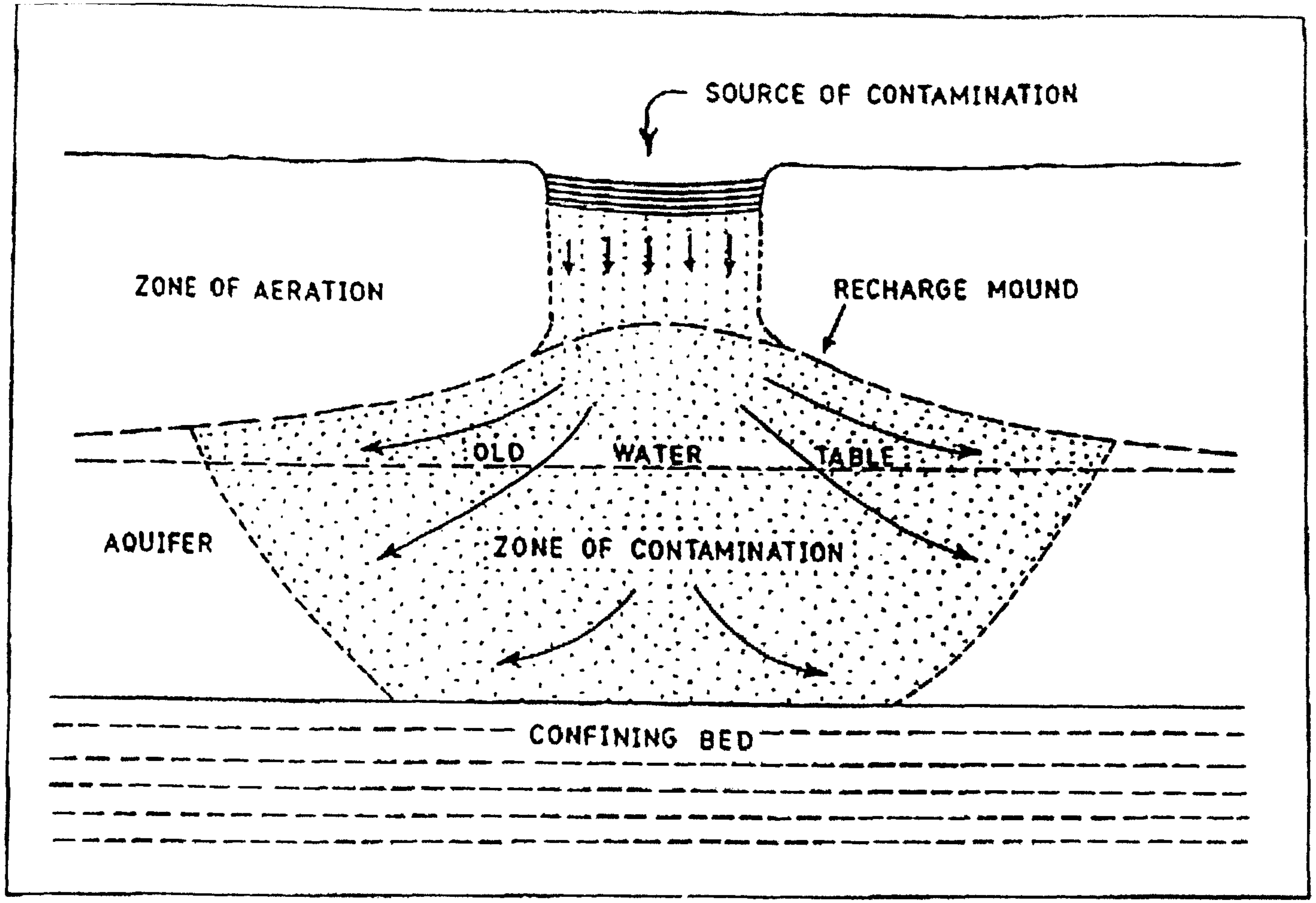


Fig. 5.4: Percolation of contaminants from a disposal pit to a water table aquifer.

(2) Industrial sources of groundwater pollution:

Industrial wastes or effluents seriously pollute most of the Indian rivers and freshwater streams. The wastewaters of different industries in the study area such as petrochemical complexes, fertilizer factories, oil refinery, textile and dyeing industries are constantly polluting the river Yamuna.

Untreated or partially treated industrial effluents are the major source of surface and subsurface water pollution in the area. Groundwater pollution may occur where industrial wastewaters are discharged into pits, ponds thereby enabling the wastes to migrate down to the water table. Petroleum and petroleum products are responsible for much of the pollution. Leakage is particularly frequent from gasoline stations and home fuel oil tanks.

Food processing wastes generate large amount of organic by-products that have been disposed off in wastewater, when the wastewater is discharged, it leads to high BOD and consequent oxygen depletion in the receiving water. The production of oil and gas is usually accompanied by substantial discharges of wastewater in the form of brine include Na^+, Ca^{++}, NH_3, Ba, Cl^-, SO_4^{2-} and high TDS.

There are large numbers of metal industries in the study area that keep a wide array of contaminants in their wastewater. The specific contaminants and concentration depends on the particular manufacturing process employed. For instance steel mills contaminate water in coking of coal, the pickling of steel and the washing of flue glasses from blast furnaces. These waters after use tend to be acidic and have various substances like phenol, cyanogens, ore cake and fine suspended solids.

The effluents released from pulp and paper-processing operations have been a mixture of various chemicals, which have been toxic to fish. This effluent has been brownish in colour and lowers the photosynthetic rate of aquatic communities by hindering sunlight percolation into the water column. The organic waste from these plants increases the BOD of the receiving water and further lowers oxygen levels. Percolation of these wastes with water into the groundwater causes degradation in the quality of groundwater.

The industrial wastewater can be broadly classified as non-fermentable inorganic, fermentable organic and toxic wastes. The effluents discharged by metal industries steel mills, transformer manufacturing industries are termed as non-fermentable wastes and are generally characterized by low pH and high concentration of trace elements. The industrial effluents discharged by food and beverage industries are termed as fermentable wastes. The industrial wastes discharged by fertilizer, pesticides, herbicides and fungicides manufacturing industries, are toxic wastes.

Various parameters that have potential for groundwater pollution and are associated with wastewater discharged by different major industries, are given in Table-5.2.

Table 5.2: Industrial wastewater parameters with significant groundwater pollution potential

	Industries/Units	Parameters having groundwater pollution potential
1.	Pulp and paper	Phenols, color, sulphide, nitrogen, heavy metals, phosphorous, TDS
2.	Steel industries	Cyanide, phenols, iron, tin, zinc, chromium
3.	Petroleum refining	Color, copper, chloride, cyanide, iron, lead, zinc, nitrogen, odor, phosphorous, sulphate, turbidity
4.	Organic chemicals industry	Phosphorous, heavy metals, phenols, cyanide, nitrogen
5.	Inorganic chemicals, alkalies, chlorine industry	Chlorinated benzenoids and poly-nuclear aromatics, phenols, fluoride, mercury, phosphorous, cyanide, titanium, lead, copper, aluminium, boron, arsenic
6.	Plastic materials and synthetic industry	Nitrate, phosphorous, organic nitrogen compounds, chlorinated benzenoids and poly-nuclear aromatics, ammonia, cyanide, zinc
7.	Nitrogen fertilizer industry	Sulphate, organic nitrogen compounds, zinc, calcium, COD, Iron, pH, sodium, phosphate
8.	Phosphate fertilizer industry	Acidity, aluminium, arsenic, mercury, iron, nitrogen, sulphate, uranium, fluoride, cadmium
9.	Electroplating	Cyanide, chromium, nickel, copper, iron, cadmium

(3) Agricultural sources of groundwater pollution:

Agricultural source and cause of groundwater pollution is mainly irrigation return flow, includes with animal wastes, fertilizers and pesticides.

Irrigation return-flow is an important source of water pollution. Approximately two third of the water applied for irrigation of crops is consumed by evapo-transpiration, the remainder termed as irrigation return flow, which drains to surface channels or joins the underlying groundwater. The degradation results from the addition of salts by dissolution during the irrigation process. Principal cations include Ca^{2+}, Mg^{2+} and Na^{+}, major anions include HCO_3^-, SO_4^{2-}, Cl^- and NO_3^-. Irrigation return flow can be the major cause of groundwater pollution in arid and semi-arid regions.

The wastewater of Yamuna river is being utilized for irrigation in rural areas of Agra. These wastewaters are contributed mainly by domestic uses, dyeing industries, plastic industries, and food and beverage industries etc. The wastewater of Yamuna river contain high concentration of heavy metals, organic matter and other toxic substances. The concentration of TDS is high; therefore, when used for irrigation makes the soil saline. Percolation of this water into ground causes deterioration of groundwater quality.

The problem that is associated with pesticide, is presence of pesticide residue. As the pesticides residue remain in biosphere and lithosphere for more than twenty years, even if we stop using of pesticides, long-term effects that might occur could be related to carcinogenic, mutagenic and tetratogenic (ability to produce congenital utero-malformation, Silvey, W.D., 1967).

Groundwater pollution in the study area:

The potential factor, which is very common and adverse for city life, is groundwater pollution. The groundwater of Agra city is very much polluted (Dayal and Singh, 1991). They have observed that most of the samples collected from dug wells, handpumps, bore wells, tap water, etc. are of poor quality on account of bacteriological contamination. Dug wells show significant bacterial contamination. Even handpumps, bore wells and tube wells near sewer systems are more contaminated. They have reported high contamination of nitrate, chloride and phosphate besides recording its severity within a radius of about 200 m from their respective septic tanks in the city area. It is observed from the analysis of groundwater of city area that the concentration of Cr, Ni, Mn, Cu etc. are within the permissible limits of drinking water. However, the level of Zn and Fe exceeds the permissible limits in the water of handpumps.

The storm sheering creates storm run off and infiltration along natural drains (*nalas*) flowing through the city areas. The common chemical pollutants of both surface and groundwater are sulphate, nitrate, phosphate, chloride, sodium and calcium ions. Sulphate enters in groundwater both by fallout from polluted urban air and as sewage effluents. Important sources of nitrate are fertilizers and sewage effluents. Phosphate is contributed in part by fertilizers and by detergents in sewage effluents. Chloride and sodium are contributed both by fallout from polluted air and spraying of bleaching powder, etc. on roadside drains. Instances are recorded in which water supply wells and hand pumps close to roads and sewers have high concentration of salts.

The sewage systems installed for domestic, industrial and surface water drainage, increase the amount of water borne toxic and bacteriological wastes in response to the growth in population and industries related to tannery. Further, the change in water quality are intimately linked with the consequences of the increase in building density.

5.3 CONTROL OF GROUNDWATER POLLUTION:

The pollution control measures vary with the industries and hydrogeological conditions, prevalent in the area. In general, following measures can be useful in controlling groundwater pollution:

(1) ***Wastewater treatment:*** The main purpose of wastewater treatment is to reduce the amount of suspended solids, bacteria and oxygen demanding materials in wastewater. The wastewater treatment generally falls into two broad classes. Primary treatment, which involves removal of grit, screening, grinding flocculation and sedimentation. The secondary treatment involves controlled biological assimilation and degradation processes that occur in nature by microorganisms.

The most common methods used for industrial effluents include chemical oxidation, air stripping, biological treatment, electrodialysis and reverse osmosis.

(2) ***Manipulation of subsurface gradient:*** Groundwater pollution can be decreased by manipulation of subsurface gradient by injection or withdrawal of water. The basic objective is plume manage which is achieved by designing well system to control movements of water phase directly and indirectly. Well systems are also used for recovery of immiscible pollutants.

(3) ***Surface water control by capping all liners:*** Surface water control measures reduce potential infiltration by minimizing the amount of surface water flowing into a site. Capping is designed to minimize the infiltration of surface water or direct precipitation. Impermeable liners

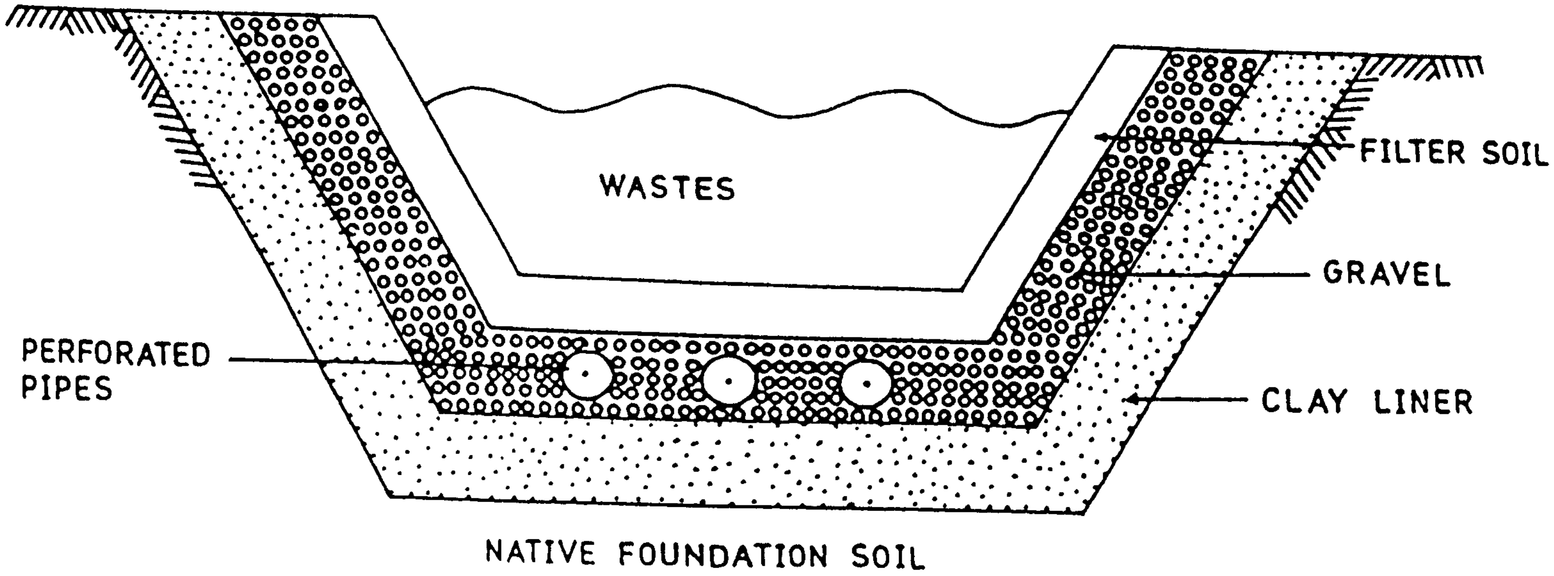


Fig. 5.5: Cross section of a single clay linear

provide groundwater protection by inhibiting downward flow of leachate and attenuating pollutants by adsorption process.

(4) ***Impermeable barriers:*** Highly toxic pollutants in groundwater can be isolated by use of barriers such as steel sheet piles, grout curtains and slurry walls. Barriers are designed to influence the subsurface gradient by placing a low permeability material into the subsurface. Sheet piles provide immediate impermeability while grouts and slurries are emulsions that require a hardening period to achieve impermeability.

(5) ***In situ treatment:*** The insitu treatment can be chemical or biological treatment. These methods involve addition of materials to the subsurface so as to increase the rate of reaction that may remove or immobilize the contaminants. Chemical technologies attempt to immobilize contaminants through chemical reactions. Whereas biological techniques are designed to utilize contaminants as food source by microorganism. In India wastewater treatment technology is being utilized that too by selected industries.

Pollution control in the study area:

The water resources of the study area at places lie a few meters below the ground surface and can often be polluted from privies, cesspools, septic tanks, barnyard manure, industrial and agricultural wastes disposal. All such contaminated water would seep into the ground

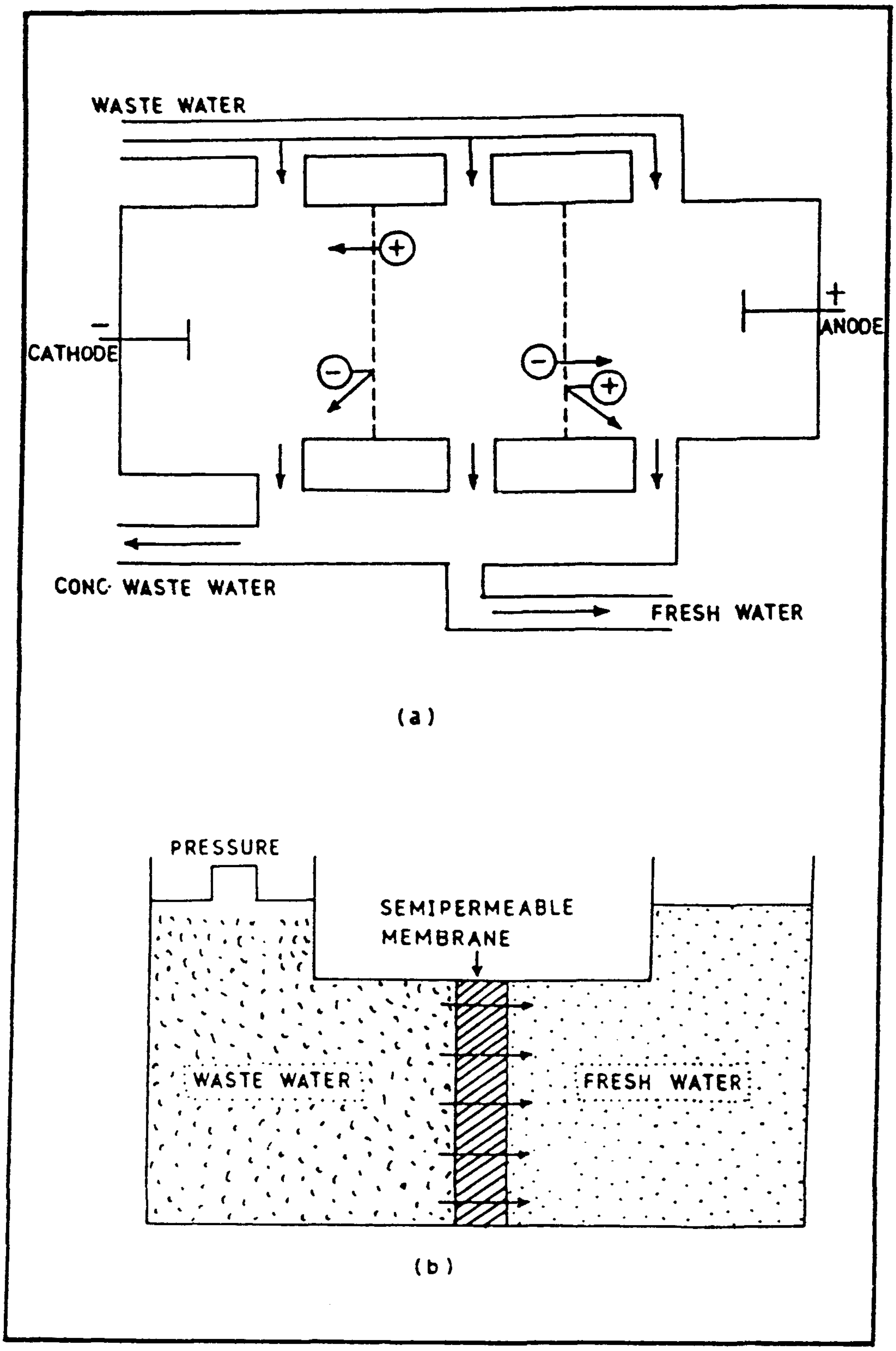


Fig. 5.6: Treatment of water by (a) Electrodialysis (b) Reverse Osmosis

to some degree, yet can latter be retrieved in a completely satisfactory condition after purification for domestic and other human uses. The natural processes occurring in soil to purify water traveling through them are essentially as follows:

(a) Removal of microorganisms and disease producing bacteria in granular zones.

(b) Natural filtration and sedimentation of suspended material in the pore spaces. The nature of pore spaces depends upon the porosity and permeability of the materials in the vadose zone and those in aquifer below.

(c) The natural die away of bacterial contaminant in groundwater depends on duration and distance of travel of the resource from the point of infiltration.

Pollutants in the study area present in soils usually move downward from the source until it reach the water table, then along with the groundwater flow from west to east towards Yamuna river. However, Yamuna water is being polluted through several sewer water too. Bacterial pollution of groundwater occurs when the groundwater has direct connection with the polluted water at or near the surface. But chemical pollution has wide distribution, as reported by earlier workers from Agra city. It is therefore, suggested that tube wells, handpumps, etc.

should be kept away from sewer system and other such sources. A special drainage system should be provided for wastewater, sewer water, etc. and modalities for their recycling be evolved through effective treatment so that the society receives the full benefit with due regard to environmental concern. It should not be permitted to drain directly to Yamuna river. The recommended minimum distance of well points from various pollution sources are given in Table-5.3.

Table-5.3 Minimum distance of well point from source of pollution.

Source of Pollution	Recommended minimum distance (m)
Septic tank or sewer of tightly joined tile, etc.	16
Earth pit privy, seepage pit or drain field	23
Cesspool, receiving raw sewage	31

Source: Health Service, A.I.D. 1969.

Owing to demographic pressures which has exponentially multiplied the demands, it is felt highly essential in the old city area, particularly in Tajganj and south of Tajganj, where such type of pollution sources still exist, to introduce sustained management of well sanitation practices on a long term. Such an assertion to overcome social crisis tends to adopt strategy to seal off the abandoned wells and the wells which are in disuse or, clean and rejuvenate them in the old city area to combat the water scarcity and to ease the water supply position besides preventing the source of pollution, particularly in Shahganj, Tajganj, Rakabganj, etc. where unregulated human activities have brought on some deleterious efforts on water management plan for optimization of benefits.

5.4 URBANIZATION AND GROUNDWATER:

Hydrogeological characteristic of an urban area gets modified in a number of ways. As stated earlier, the most important factors that affect it are increase in population density and built up area.

Population and water demand:

As the population of urban agglomeration increases, the water supply demand too begins to show a rising trend. This is the first primary problem that is experienced in day-to-day life. The population growth vis-à-vis water supply and demand of Agra city is presented in Table-5.4. The growth in demand is further accelerated as standard of living is raised. This compounds the problem to search and develop adequate and sustainable water resources for domestic uses.

Built-up area:

A sizable percentage of the land surface has been rendered impervious for infiltration of water by constructing roofs, roads, lands, pavements and parking. It has been estimated and worked out that in the residential complex, impervious area amounts to about 25 to 80 per cent (Hall, 1984). An increase in proportion of built-up surface reduces infiltration and increases surface run off from the urbanized area. In addition to increase in surface run off, there is a reduction of recharge to the groundwater regime and base flow to Yamuna river. This is further depleted due to groundwater utilization for domestic uses by wells, hand pumps and tube wells. However, there is a well-marked rise in water table all along the Yamuna river due to bank storage in monsoon period. The stream discharge varies from low stage in lean period to flood stages during monsoon due to urbanization and storm sewers.

The change caused by urbanization is the introduction of storm sewers that allow storm run off from paved areas to be taken directly to stream channels for discharge run off, travel time to river Yamuna is thus being shortened and at the same time the proportion of run off is being increased by expansion in impervious surface. These two changes together affect tremendously.

Most of the precipitated water is being conveyed to the drainage network and finally to the Yamuna river more rapidly. This increase in flow velocity directly affects the timing of the run off hydrograph. Since a large volume of run off is discharged within a shorter time interval, peak rate of flow inevitably increases, giving rise to the problem of flood to the down stream of the river Yamuna.

Table-5.4 Population growth and water supply of Agra city

Year	Populations	Per capita water supply (lit/head)	Total water supply (MLD)	Remarks
1940	2,44,094	182	45.20	Deficient
1950	3,50,000	182	63.20	Deficient
1960-61	5,08,680	122	135.60	Deficient
1986	8,39,000	255	213.94	Deficient
1991	8,98,000	270	242.46	Deficient
1996	13,68,769	290	261.40	Deficient
2001	19,55,694	310	282.30	Deficient
2004	21,23,440	340	298.60	Deficient

Source: U.P. Jal Nigam.

Impact of urbanization on groundwater:

The foregoing facts denote that rapid urbanization and industrialization have introduced three alarming problems in the hydrogeological regimen, i.e. less groundwater recharge, greater run off causing flood problem and quality deterioration of groundwater. The consequences of such changes are outlined diagrammatically for Agra city in Fig.5.7.

Observations have amply demonstrated that in any part of Agra metropolitan area, which is subjected to the demographic stress of urbanization, the colossal deposition of sediments, which results from

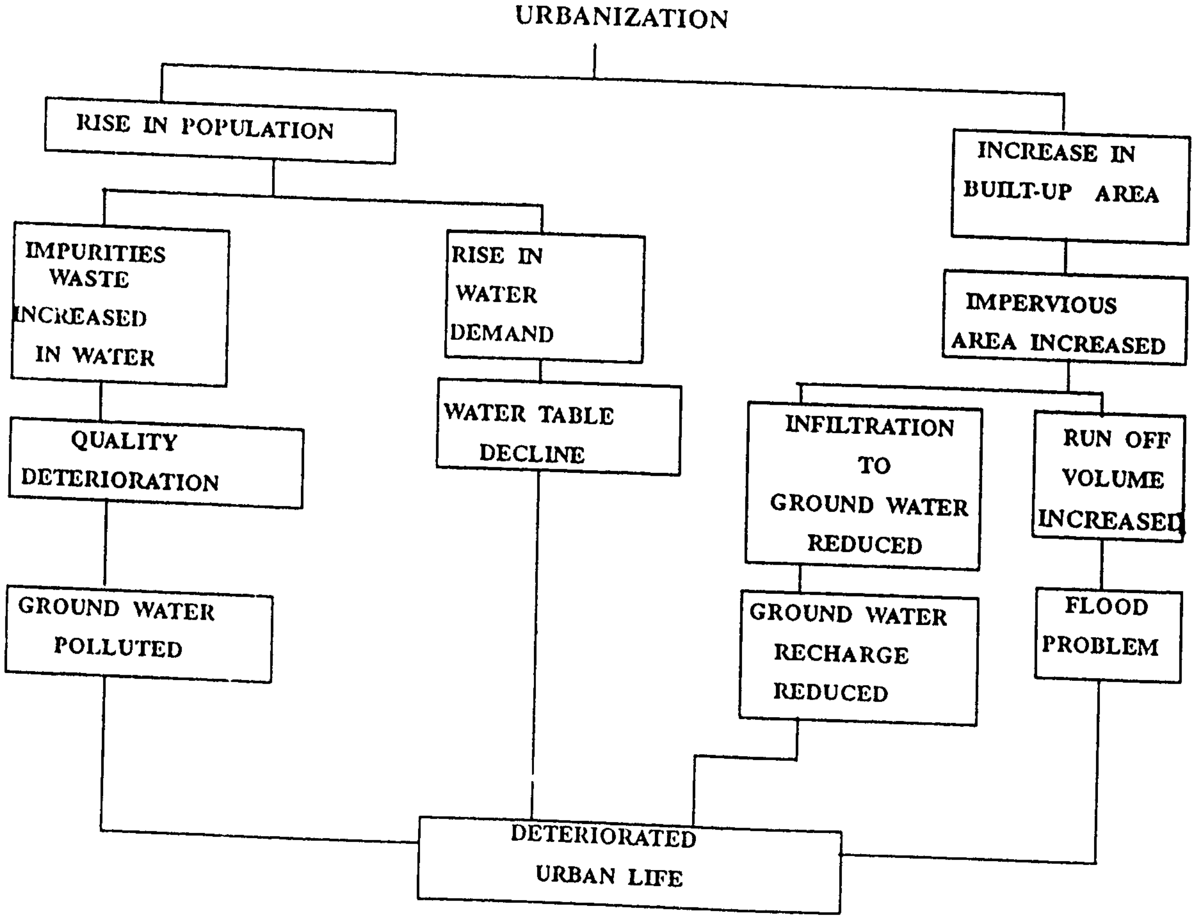


Fig. 5.7: Impact of urbanization on hydrological regime

construction activity, changed the inflow regime consequent to modification in drainage geometry. Sometimes it changes the physical and biological environment around the city area. The constructed pits of brick kilns of Jagner and other roads around Agra city are being used as dumping ground for solid municipal wastes, which results in the deterioration of groundwater quality. This phenomenon is found in almost all developing cities and warrants for a critical review, and monitoring mechanism suitably developed for quantitative appraisal with time and space, periodicity of which should be consonant to gravity of generated/generating means.

5.5 WATER CONSERVATION ASPECTS AROUND STUDY AREA:

Precipitation, the major source of fresh water around Agra city, is to be harnessed and stored properly either in aquifer reservoirs in form of groundwater or by constructing storage reservoirs to hold surface flow. These storages, either subsurface or surface, have to be protected against losses and hazards of pollution. The major problem in storage of water under the ground is due to sewage blockage or leakage causing pollution of groundwater. Similarly, major losses in surface storages are evaporation, seepage and infiltration. It is, therefore, increasingly felt in suitably designing and implementation of effective and viable measures for preventing pollution of groundwater and surface water. Besides the above, well-planned measures towards preventing evaporation and seepage losses are imperative.

Rainwater harvesting and its collection in low land areas of nearby villages will help in uses like emergency irrigation, cattle's need, etc. In addition, it would gradually recharge groundwater and replenish nearby drinking water wells. There is an urgent need to preserve and protect such tanks and ponds, which have many uses in long-term perspective of water conservation. More emphasis needs to be given for recharging of aquifers, which are under the influence of over exploitation and orientation of future action plan options accordingly directed and implemented.

The open lands and uplands in the study area should be taken up in planned way to ultimately retain water on the site for a longer time. This will increase soil moisture and delay the localized run off. Conservation work of upland terraces around Dayalbagh, Swamibagh and implementation of proper sewer systems and other surface amendments to reduce run off velocities and related surface erosion are to be taken up in a planned and systematic way to contain the persisting adversities.

Chapter-6

Hydrochemistry

HYDROCHEMISTRY

Water is one of our basic natural resources, water from surface and underground sources provides sustenance to plants and animals, constitutes the habitat for aquatic organisms, and meets important agricultural and industrial needs. Water is the only substance on the earth that appears in three distinct form of matter within the normal range of the climatic condition. Water is the most vital resource for all kinds of life on the earth, which adversely affected both qualitatively and quantitatively by all kinds of human activities on land, in air or in water. Groundwater is generally an extreme dilute aqueous solution of carbonates, bicarbonates, sulphates, chlorides of alkali metals and alkaline earths. The concentration of elements in natural water is governed by several factors like nature of strata through which they are circulating, soil characteristics, contamination due to activities of man etc. Understanding of the quality of water is useful for evaluating its usability in domestic, agricultural and industrial water supply. Suitability of water for various purposes is based on chemical and biological character of the water.

6.1 MATERIALS AND METHODS

Collection of water samples:

The objective of sampling is to collect a portion of material small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material being sampled. Before collecting samples from distribution systems, flushliness sufficiently to ensure that the sample is representative of the supply, samples are collected from wells only after the well has been pumped sufficiently to ensure that the sample represents the groundwater source.

In order to study the quality of groundwater of Agra, twenty-one groundwater samples were collected from shallow and deeper aquifers. In the study area the samples were collected from hand pipes and tube well analysed for major elements and trace elements. The samples have been collected in a clean bottle by washing them with concentrated HNO_3 or H_2SO_4 and distilled water. After collection of samples, the bottles were capped with inner-lid and sealed. For trace elements, the samples were collected separately and treated with 5 ml 1:1 HNO_3 and then capped and sealed.

There are various factors which effects the analytical results include presence of suspended matter, the method chosen for its removal

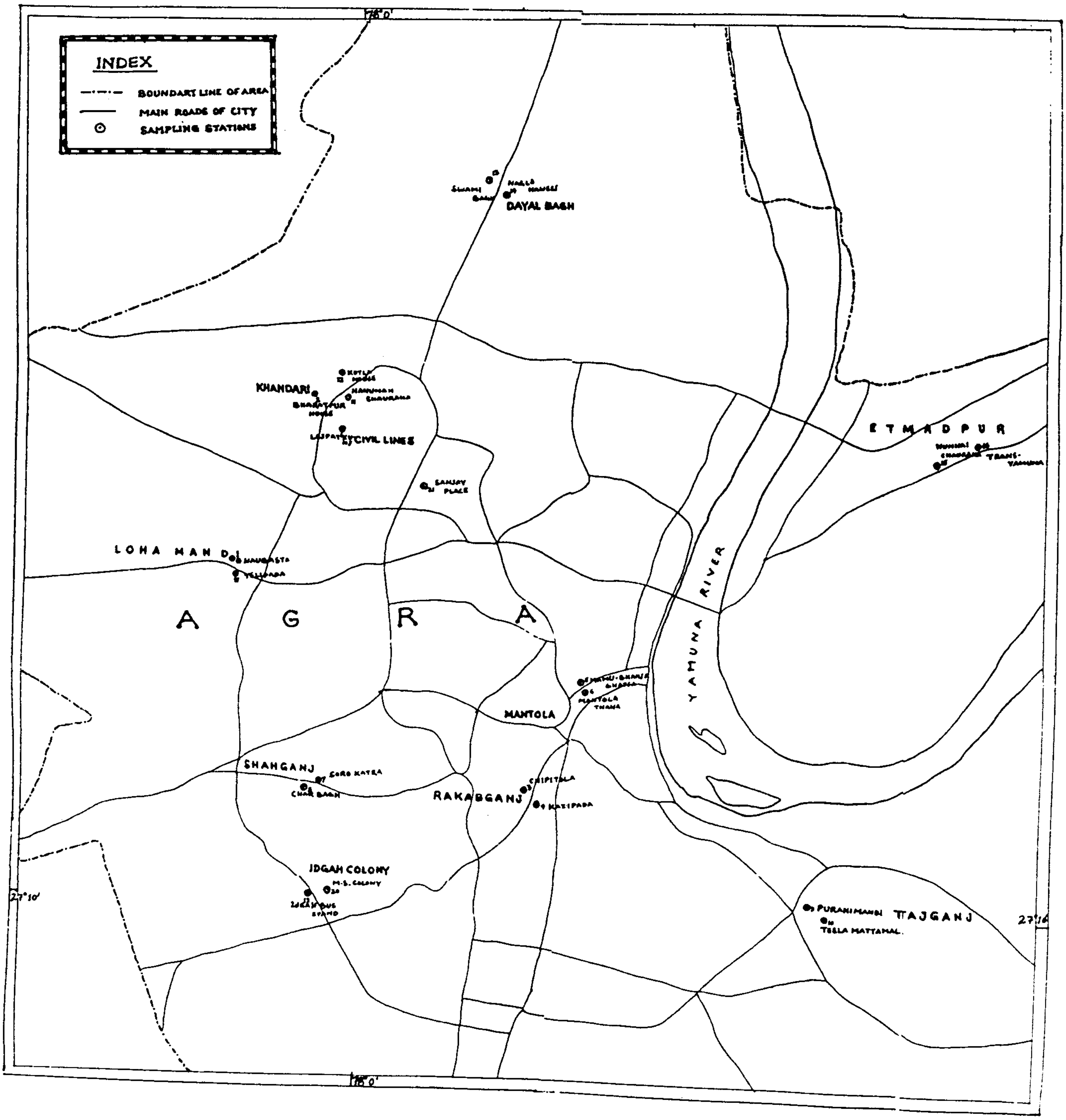


Fig. 6.1: Sampling location map of the study area.

and the physical and chemical changes brought about by storage or aeration. To avoid this, the following precautions have been taken before collecting samples:

(1) Water samples are collected from wells only after the well has been pumped sufficiently to ensure that the sample represents the groundwater source.

(2) Before collecting the sample from hand pipe, sufficient water has been pumped.

(3) Special precautions are necessary for samples containing organic compounds and trace elements, which may be present at concentration of microgram per liter.

Preservation of water samples:

Sample preservation techniques only retard chemical and biological changes that continue after sample collection. Complete preservation of water samples is practically impossible. Regardless of the nature of the sample, complete stability for every constituent can never be achieved. The water samples were to be collected in a separate clean bottle and acidified with nitric acid to pH below 2.0 to minimize precipitation and adsorption of certain cations such as AI, Cd, Cr, Cu, Fe, Pb, Mn, Ag and Zn. To minimize the potential for volatization or biodegradation between sampling and analysis, the samples have been kept under storage at 4°C as recommended by W.H.O. (1984). Methods of preservation are used to retard hydrolysis of chemical compounds, retard biological action and to reduce volatility of constituents and it is given in the Table 6.1.

Table 6.1 Methods of Preservation for different parameters

S.No.	Parameters	Preservation	Maximum holding period
1.	Acidity/Alkalinity	Refrigeration at 4°C	24 hours
2.	Conductivity	Refrigeration at 4°C	28 days
3.	Colour	Refrigeration at 4°C	24 hours
4.	Sulphate	Refrigeration at 4°C	7 days
5.	BOD	Refrigeration at 4°C	6 hours
6.	COD	2 ml sulphuric acid/l	7 days
7.	Sulphide	2 ml zinc acetate/l	7 days
8.	Total metal	5 ml nitric acid/l	6 months
9.	Calcium	None required	7 days
10.	Chloride	None required	7 days
11.	Fluoride	None required	7 days
12.	Hardness	None required	7 days
13.	Turbidity	None required	7 days
14.	TDS	None required	7 days
15.	DO	Determined on site	--
16.	PH	Determined on site	--

6.2 ANALYTICAL TECHNIQUES USED FOR WATER SAMPLES:

All the major ions have been analysed by Volumetric Method except sodium and potassium. Sodium and potassium were analysed with the help of Flame Photometer. Atomic Absorption Spectrophotometer was used to analyze the trace elements present in the water samples. Water analysis kit has been used for analysis of E.C., pH and T.D.S.

Volumetric Method:

Determination of major ions such as Ca, Mg, Na, K, Cl, CO_3, HCO_3, SO_4 and hardness are taken place by Volumetric Method. This method can be classified into four types:

(i) Acid base titration method

(ii) Redox reaction method

(iii) Precipitation method

(iv) Complexometric method

The acidity or alkalinity of water samples was determined by using Acid-base titration. Redox titration is the most reliable for analysis of DO, BOD and COD. The Precipitation titration has wide-ranging applications in the analysis of water samples e.g. the determination of the sulphate and chloride. The hardness of water has been determined by Complexometric titration method.

Determination of chloride has been done by using a different method, what is called Argenometric Method. This method is based on the principle that in a natural or slightly alkaline solution, potassium chromate ($K_2Cr_2O_7$) can indicate the end point of the silver nitrate ($AgNO_3$) titration of chloride. Silver chloride ($AgCl$) is precipitated quantitatively and red silver chromate is formed.

Water Analysis Kit:

E.C., pH and T.D.S in water samples were determined with help of water analysis kit. Various electrodes have been used for determination of these parameters.

Determination of pH: pH is the most important in water chemistry, which is the measure of acidity or alkalinity of water samples. Measurement of pH with water analysis kit is accomplished by determining the potential developed by different electrodes.

***Procedure*:** The pH electrode is connected to the input socket at the front of the instrument. Electrode is cleaned with distilled water and dipped in the 4.00 pH buffer solution, which is supplied with the instrument. After measuring the temperature of the buffer solution, temperature knob is fixed at the temperature of the solution. After pushing the pH switch with help of calibration knob, the display to 4.00 pH is adjusted. The electrode is washed, dried and dipped in the solution whose pH is to be measured. After keeping the temperature at the proper position, reading of pH can be noted.

Determination of E.C.: E.C. is the measure of the ability of a solution to carry electrical current that depends on presence of ions, their total concentration, mobility, and valence and on the temperature of measurements.

***Procedure*:** The conductivity cell is connected to the input socket for conductivity. The cell is dipped in 0.1 N KCl solutions whose specific conductivity is known. After pushing the conductivity switch, conductivity range is adjusted at 200 μmhos. After measuring the temperature of the solution, reading is adjusted with the help of calibration knob as per the chart supplied with the instrument. Conductivity cell is washed with distilled water and dipped in the solution whose E.C. is to be measured. After selecting the proper conductivity range, it will give direct reading.

Atomic Adsorption Spectrophotometer:

Photometry refers to the measurement of the light transmitting through a solution, which is the transmitting power of the solution in order to determine the concentration of light absorbing substances present in the solution.

In spectrophotometer, monochromatic light is passed through an absorbing column of an often colored solution of a fixed depth and directed upon photosensitive device, which converts the radiant energy into electrical energy. The current produced under these conditions is measured by means of a sensitive voltmeter.

In this method the sample is atomized and aspired into flame, a light beam is directed through the flame into a monochrometer and on to a detector, that measure the amount of light absorbed. Absorption measured in photometer involves not only the absorbance of the solute in the solution, but also all the molecules of the liquid through which the light passes. The greater the number of molecules or ions of absorbing substances present, the greater is the absorption of light In other words, the more the color, the greater is the deflection of the voltmeter. Thus, the concentration of absorbing component present in a solution may be accurately measured by Atomic Absorption Spectrophotometer.

Flame Photometer:

The principle involves in Flame Photometry Method is that salts of metals when introduced under carefully controlled condition into a suitable flame are evaporized and exited to emit radiations that are characteristics for each element. In this method solution of sample is atomized and sprayed into a burner. The intensity of the light emitted by a particular spectral line is measured with the help of photoelectric cell and galvanometer. Sodium and potassium were determined by this method.

6.3 WATER QUALITY PARAMETERS IN THE STUDY AREA:

The quality of water largely depends on a number of parameters including hydrological, physical, chemical and biological parameters. These are of special importance deserving frequent attention and observation; others give a rough picture of water quality status. The water quality parameters have shown in Table 6.2 that have been analysed during the study.

The physiochemical parameters and hydrochemical data of the water samples taken during both premonsoon and postmonsoon are given in the Appendix-I and Appendix-II. The concentrations of trace elements in the water samples during premonsoon and postmonsoon have also shown in the Appendix - III and Appendix - IV, respectively. The entire

Table 6.2. Water quality parameters in the study area

S.No.	Physical parameters	Chemical parameters	Major cations	Major anions	Trace elements
1.	E.C.	Hardness	Magnesium	Bicarbonate	Manganese
2.	-	T.D.S.	Potassium	Carbonate	Chromium
3.	-	PH	Calcium	Chloride	Copper
4.	-	-	Sodium	Sulphate	Nickel
5.	-	-	-	-	Cobalt
6.	-	-	-	-	Zinc
7.	-	-	-	-	Iron

physical and chemical data has been summarized in the form of average values and are given in the respective tables.

The different parameters, which have been analysed in the area during the present study, are discussed below:

6.4 PHYSICAL PARAMETERS:

As shown in the Table 6.2, the physical parameter that is taken in account during the study is Electrical Conductivity.

Electrical Conductivity (E.C.):

Electrical Conductivity is the measure of capacity of water or solution to pass electric current and have the direct relationship with the concentration of ionized materials present in the water or solution.

Electrical Conductivity is reciprocal of the resistance. It gives idea about extent of mineralization and is indicative of the salinity of water.

The value of E.C. ranges from 700 µs/cm to 4000 µs/cm at 25°C in the groundwater during premonsoon period. It has an average of 2128.57 µs/cm during this period. The groundwater around Idgah bus stand and M.S. Colony shows highest value of E.C. as 4000 µs/cm during premonsoon period, which may be due to high mineralization. The lowest value of E.C. as 700 µs/cm is observed in the water samples taken from Dayalbagh.

During postmonsoon, the value of E.C. ranges between 900 µs/cm and 3300 µs/cm in the groundwater of the study area with an average of 1771.4 µs/cm. The highest value of E.C. has been observed at Idgah bus stand area, which is 3300 µs/cm during this period. The lowest value of E.C. as 900 µs/cm is recorded in Dayalbagh.

6.5 CHEMICAL PARAMETERS:

The chemical parameters include pH, which is the concentration of hydrogen ions, the Total Dissolved Solids (T.D.S.) and Hardness which is measured as $CaCO_3$.

Hydrogen ion concentration (pH):

pH is the measure of the intensity of acidity or alkalinity of water and represents the concentration of hydrogen ion present in the water. In other words, hydrogen ion concentration in water is the logarithmic reciprocal of their weights measured in grams per liter of water. It should be noted that pH does not measure total acidity or alkalinity. The normal acidity or alkalinity depends upon excess hydrogen ions, which are more than hydroxyl ions over the other. If free hydrogen ions are more than the hydroxyl ions, the water shall be acidic. The pH value of acidic water varies from 0 to 7 and that of alkaline water between 7 and 14, while it will be 7 for neutral water. Generally, the fresh water has a pH value of 6.5- 8.5. pH is generally measured on a log scale and is equal to negative $\log_{10}$ of hydrogen ion concentration.

In the study area, the pH values of groundwater ranges from 7.1 to 8.8 with an average of 7.8 during premonsoon period. The highest value of pH as 8.8 is recorded at Sorokatra of Shahganj area, while the lowest value is observed as 7.1 in the water samples of Dayalbagh and Idgah bus stand during this period.

During postmonsoon period, the values of pH slightly deviate and ranges between 7.3 and 8.9 with an average of 7.8. The area representing the highest value of pH as 8.9 is Sanjay place while Teela mattamal of Tajganj area shows the lowest value as 7.3.

Total Dissolved Solids (T.D.S.):

Total Dissolved Solids represent the total chemical constituents or minerals present in the water. In natural waters Total Dissolved Solids are mainly composed of carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of Ca, Mg, Na, K, Fe and Mn etc. Concentration of dissolved solids is an important criterion, which measures the suitability of water for drinking and other water quality standards. The permissible limit of T.D.S. prescribed by I.C.M.R. (Indian Council of Medical Research, 1975) is in between 500 ppm and 1500 ppm.

During premonsoon, the groundwater of study area shows the T.D.S. value in the range of 448 ppm to 2560 ppm with an average value of 1362.28 ppm. The higher concentration has been recorded at Mantola and Idgah area. The highest value of T.D.S. is observed as 2560 ppm in the Idgah area, while Dayalbagh shows the lowest value as 448 ppm.

During postmonsoon period, the value of T.D.S. ranges in between 576 ppm and 2112 ppm with an average of 1133.7 ppm. The higher concentration is observed as 2112 ppm in the Idgah area while it is lowest as 576 ppm at Swamibagh and Dayalbagh. Water with high concentration of T.D.S. is generally palatable, may not quench thirst and may have laxative effect on people. A simple but widely used scheme for categorizing groundwater based on T.D.S. presented by Davis et al., 1966, has been given as follows:

Table 6.3: T.D.S. classification of water (Davis et al., 1966).

Types of water	Concentration of T.D.S. (ppm)
Fresh water	0 – 1000
Brakish water	1000 – 10,000
Salty water	10,000 – 1,00,000
Brine	More than 1,00,000

Hardness:

Hardness is the property of water that prevents the leather formation with soap. The hardness is mainly caused by the presence of carbonates of Ca and Mg and also chlorides and sulphates of Ca & Mg. It increases the boiling point of water. The anions responsible for hardness are mainly bicarbonate, carbonate, sulphate, chloride, nitrate and silicate. Hardness is called temporary if it is caused by bicarbonate and carbonate salts of cations and it can be removed by simply boiling water. Mainly sulphates and chlorides of the metals cause permanent hardness.

Water has been classified as hard or soft according to their action on the soap. The water is softer, if it takes less amount of soap to produce leather. On the basis of hardness; the classification of water is given in the Table 6.4.

The hardness in the study area ranges from 96 ppm to 920 ppm with an average of 479.66 ppm during premonsoon period. The highest value has been observed as 920 ppm at Mantola area and lowest value is recorded as 96 ppm at Sanjay Place in premonsoon period.

In the postmonsoon period, the highest value recorded is 112 ppm while, the lowest value is analysed as 16 ppm at Idgah and Mantola area respectively. The values of hardness ranges in between 16 ppm and 112 ppm with an average of 58.09 ppm during this period. According to the I.S.I. (Indian Standard Institute, 1983), the hardness of drinking water should be in the range of 300 to 600 ppm.

Table 6.4. Hardness classification of water

S.No.	Hardness (ppm)	Water Class
1.	0 – 75	Soft
2.	75 – 150	Moderately hard
3.	150 – 30	Hard
4.	> 300	Very hard

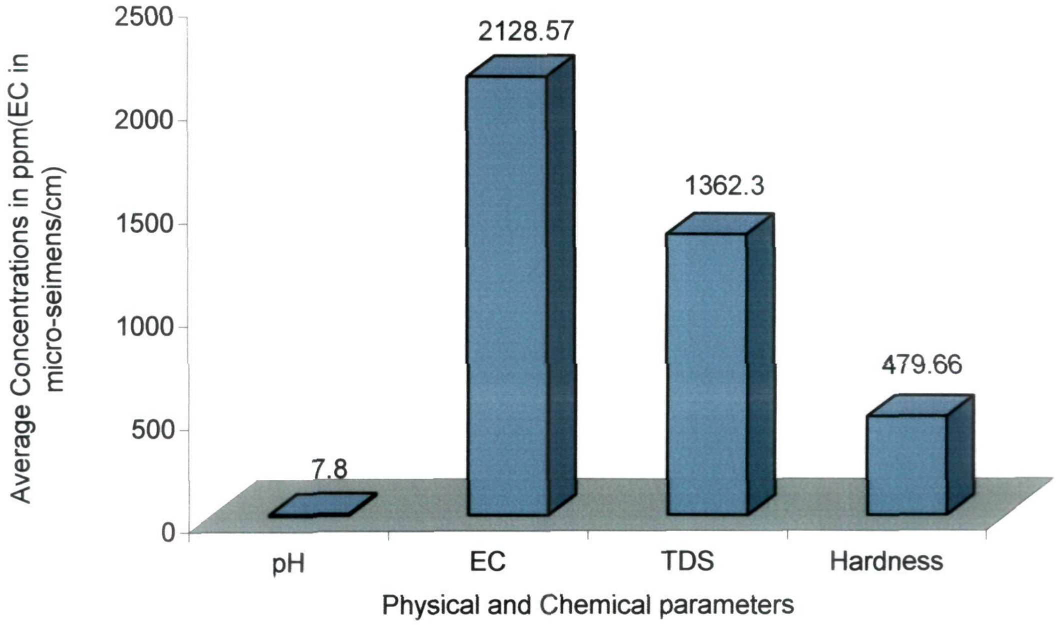


Fig.6.2: Bar graph showing average concentrations of Physical and Chemical parameters during premonsoon period (May-2004)

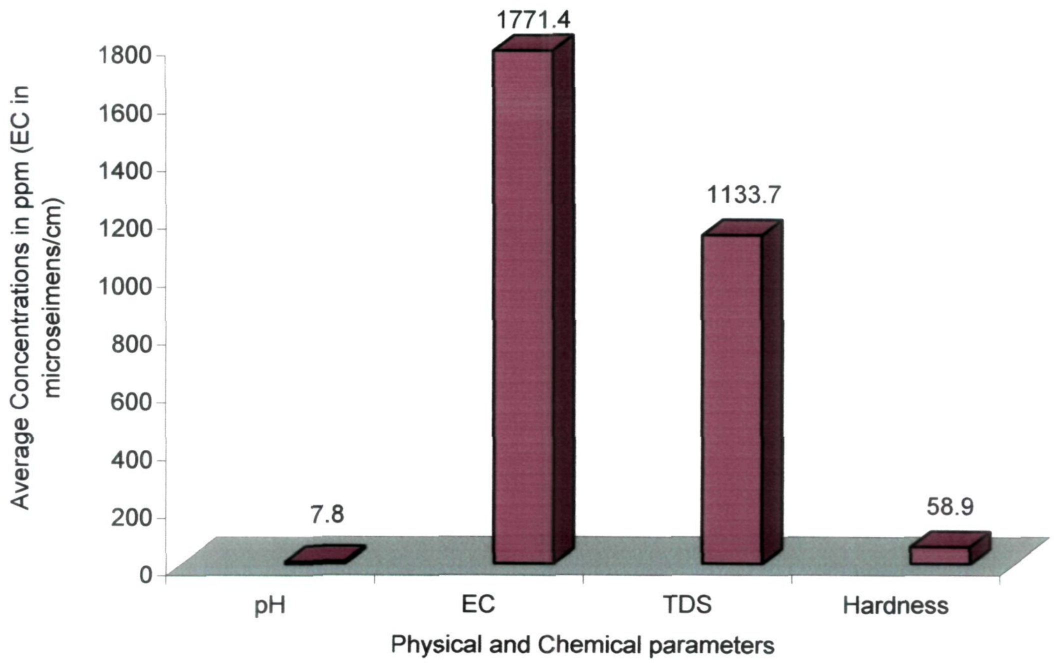


Fig.6.3: Bar graph showing average concentrations of Physical and Chemical parameters during postmonsoon period (Nov.-2004)

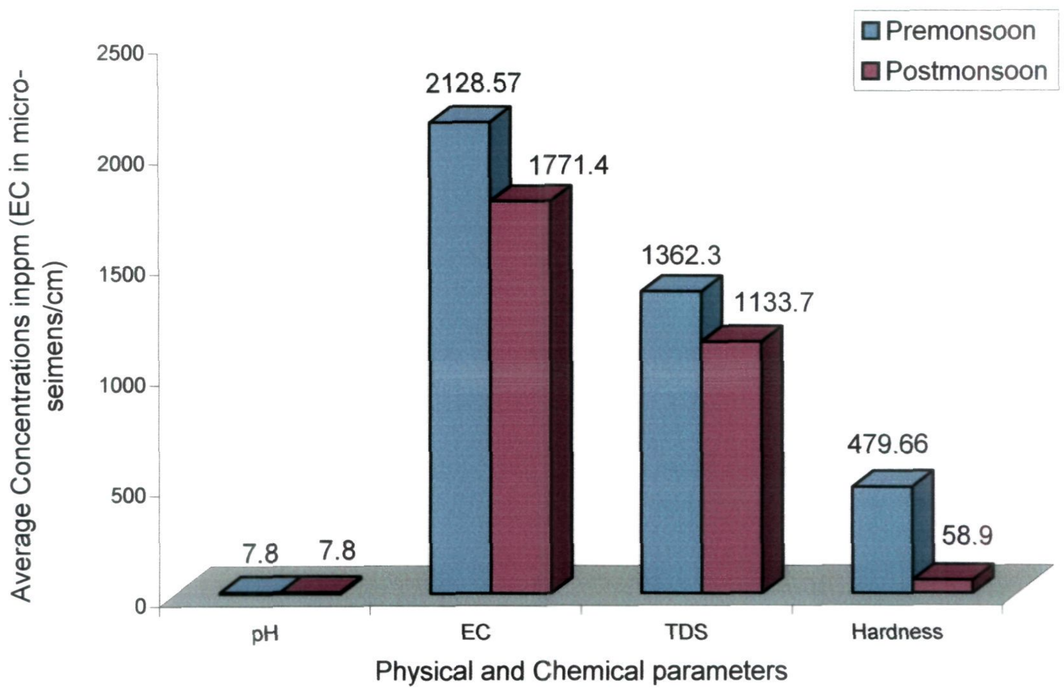


Fig.6.4: Comparision bar graph showing average concentrations of Physical and Chemical parameters during premonsoon and postmonsoon periods,2004

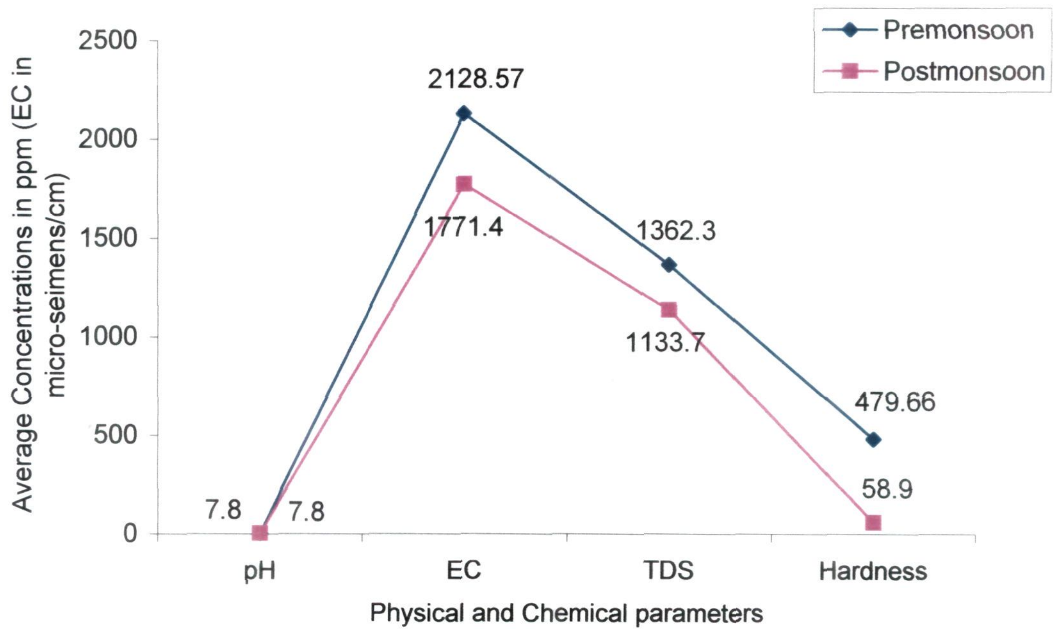


Fig.6.5: Comparision line graph showing average concentrations of Physical and Chemical parameters during premonsoon and postmonsoon periods, 2004

6.6 MAJOR CATIONS:

Major cations in the water samples of the study area were analysed as Ca^{++}, Mg^{++}, Na^{+} and K^{+}, and deserve frequent attention regarding the quality of water.

Calcium (Ca^{2+}):

Calcium is one of the most important cations of natural waters. It contaminates the water leaching from the rocks where it is present in highest quantities. The important sources of calcium in groundwater of the study area are rainwater, leaching from fertilizers, and soil amendment, weathering of calcium-silicate minerals and use of surface water for irrigation. It has got a high affinity to absorb on the soil particles; therefore, the cation exchange equilibria and presence of other cations greatly influence its concentration in waters. It is one of the important nutrients required by and has no hazardous effects on human health.

In the study area, the concentration of calcium ranges from 8.01ppm to 384.76 ppm with an average value 59.28 ppm during premonsoon period. The higher concentrations of calcium have been observed at Mamu Bhanja Ghatia of Mantola Thana area and Naubasta in

Lohamandi area. The lowest concentration is recorded at Sanjay Place as 8.01 ppm.

During postmonsoon period, the concentration of calcium ranges between 12.82 ppm to 246.89 ppm. The lowest concentration has been observed as 12.82 ppm at Kotala House while Mantola area shows the higher concentration as 246.89 ppm and 243.68 ppm. According to World Health Organization (W.H.O., 1984), the maximum permissible limit for calcium is 200 ppm. The low content of calcium may cause rickets and defective teeth. It is essential for cardiac function, nervous system and in coagulation of blood.

Magnesium (Mg^{2+}):

The lesser concentration of magnesium in groundwater is due to lesser occurrence of magnesium mineral. The principal sources of magnesium in the natural waters are sewage and industrial wastes in the area. Magnesium is supposed to be non-toxic at the concentration it generally meets in natural waters. Higher concentrations combined with sulphate acts as laxative to human being. Magnesium is an essential nutrient for human body with an average adult requirement of 200-300 mg/day.

The groundwater in the study area entertains the magnesium in the range between 7.94 ppm to 168.6 ppm during premonsoon period with an average value of 87.09 ppm, while it ranges from 1.94ppm to 145.21 ppm with an average of 45.9 ppm during postmonsoon period. The higher concentrations are observed in the Mantola area and lower concentration is shown by Sanjay Place and Civil Lines area.

According to the W.H.O. (1984), the maximum permissible limit of magnesium is 150 ppm. The deficiency of magnesium may cause severe diarrhoea, chronic renal failure and protein caloric malnutrition (W.H.O., 1984).

Sodium (Na^+):

Sodium is an important cation occurring in natural waters from weathering of various rocks, which is the known major source. The most important quality aspect of sodium is the possibility of changing the permeability of soil. Sodium has a tendency to get observed on the clay particles, but may effectively be exchanged by calcium and magnesium.

The concentration of sodium has been also analysed in terms of ppm and is shown in the Appendix-I and Appendix-II respectively. It ranges from 257.14ppm to 1114.28 ppm with an average of 650.61 ppm during premonsoon period. During postmonsoon period, the concentration of sodium ranges between 255ppm and 1138.82 ppm with an average of 552.7 ppm. The higher concentrations are recorded at Idgah and Mantola area. Water quality for irrigation is classified according to the sodium percentage and is given in the Table 6.8.

According to National Academy of Science (1977), the higher concentration of sodium can be related to cardiovascular diseases and toxemia associated with pregnancy in woman. There are no adverse effects on the health at lower concentrations of sodium. The important sources of sodium in groundwater of the study area are the disposal of sewage and industrial effluents containing sodium and the use of surface water for irrigation.

Potassium (K^+):

The potassium is not very much significant from the health point o view but large quantities may be laxative. The resources of potassium in groundwater includes, rainwater, disposal of wastewater containing potassium and use of potash fertilizer.

In the study area, the concentration of potassium ranges from 0.48 ppm to 80.48 ppm with an average of 23.02 ppm during premonsoon period. The highest concentration is recorded as 80.48 ppm at Nunhai and the lowest is observed at Dayalbagh as 0.48 ppm.

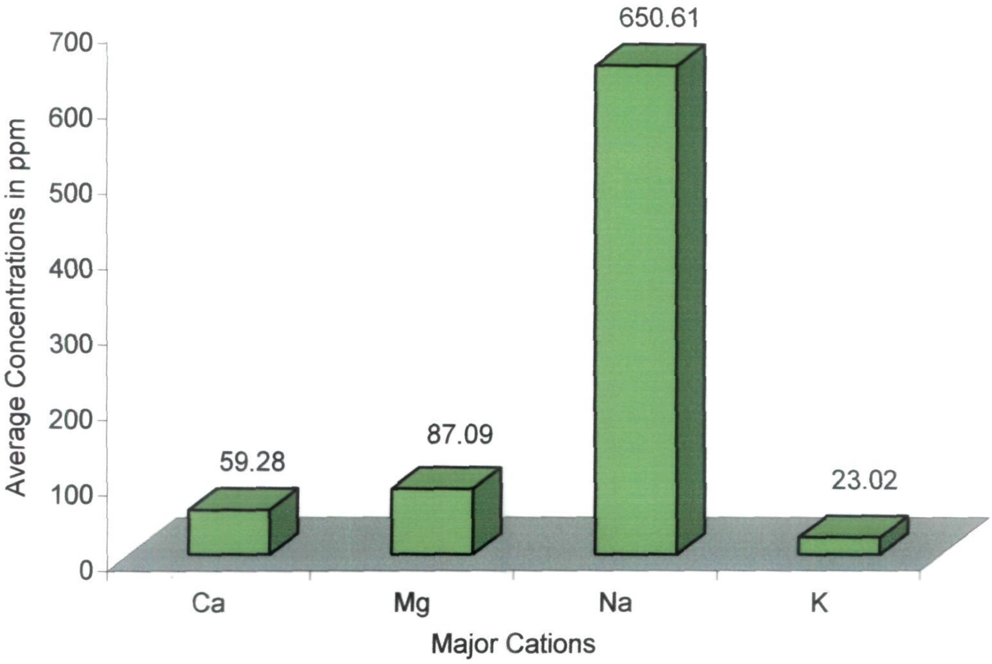


Fig.6.6: Bar graph showing average concentrations of Major Cations during premonsoon period (May-2004)

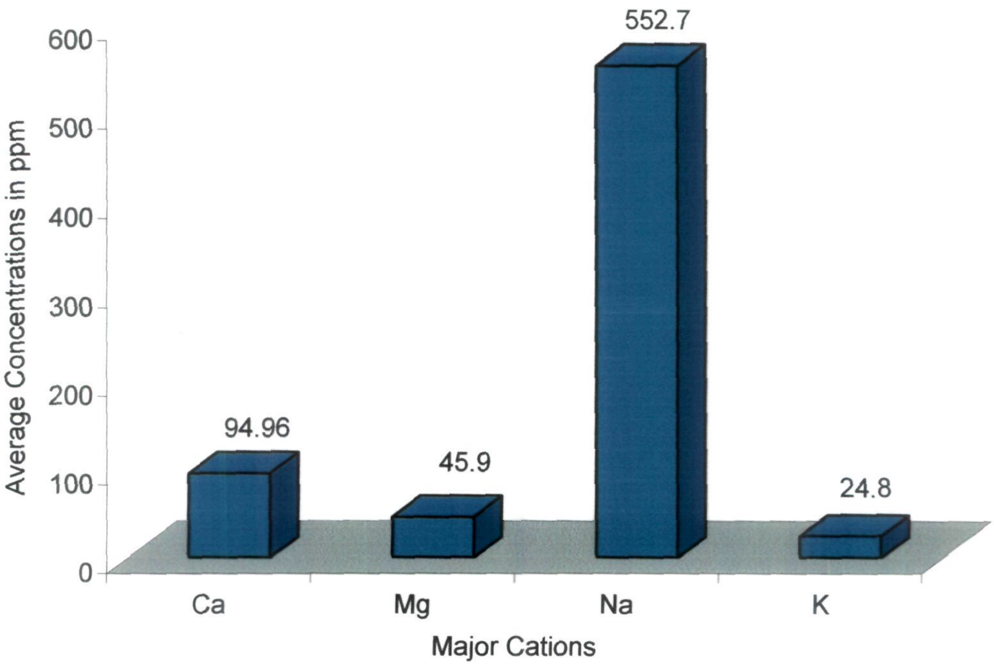


Fig.6.7: Bar graph showing average concentrations of Major Cations during postmonsoon period (Nov.-2004)

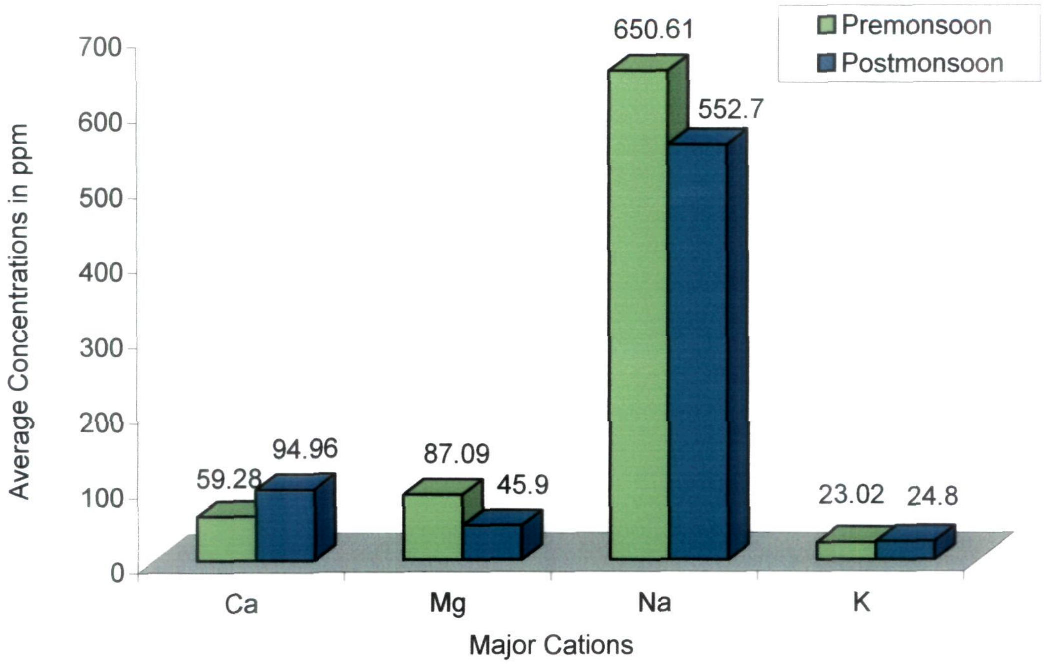


Fig.6.8: Comparision bar graph showing average concentrations of Major Cations during premonsoon and postmonsoon periods,2004

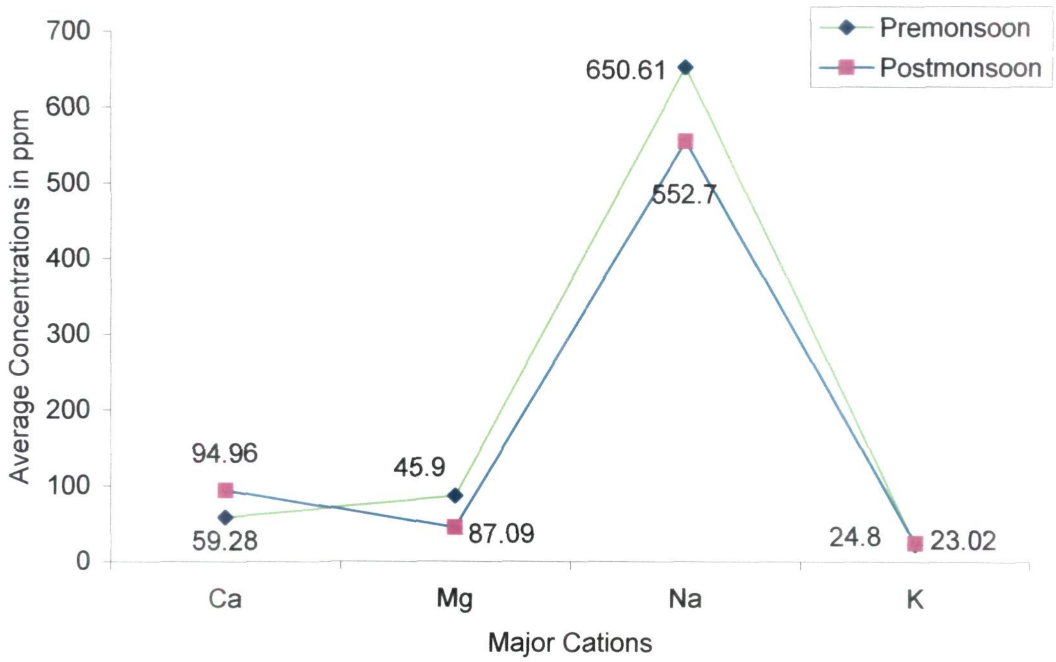


Fig.6.9: Comparision line graph showing average concentrations of Major Cations during premonsoon and postmonsoon periods,2004

During postmonsoon period, potassium concentration ranges between 3.58ppm and 87.69 ppm with an average of 24.8 ppm in the study area. Trans-Yamuna Colony of Nunhai shows the maximum concentration of potassium as 87.69 ppm while Mantola area represents the minimum concentration as 3.58 ppm.

6.7 MAJOR ANIONS:

Carbonate, bicarbonate, chloride and sulphate have been analysed as major cations in the water samples of the study area.

Bicarboante (HCO_3^-):

The bicarbonate has been found in considerable amount in the water samples of the study area during premonsoon. It is absent in some water samples during postmonsoon period. The main sources of bicarbonate in the groundwater include carbon dioxide in soil, leaching from carbonaceous rock, carbon dioxide in atmosphere and carbon dioxide released due to bacterial oxidation of organic matter.

The concentration of bicarbonate ranges from 156ppm to 388 ppm during premonsoon period with an average of 236.48 ppm. While it has been reduced during postmonsoon period ranging from 39ppm to 364 ppm with an average of 135.7 ppm and it is absent in some places during this period.

The maximum concentration is recorded in the water samples of Naubasta of Lohamandi and Mamu Bhanja Ghatia of Mantola area during premonsoon and postmonsoon periods respectively. The lowest value of bicarbonate has been analysed at Dayalbagh during premonsoon period and in the groundwater of Kotala house of Khandari area during postmonsoon period.

Carbonate (CO_3^{-}):

Carbonate is generally absent in water samples of the study area and it is observed only in few groundwater samples with an average of 32.5 ppm and 104 ppm during premonsoon and postmonsoon periods respectively. The major source of carbonate in natural fresh water is carbonaceous rocks.

The concentration of carbonate is in a range of 26 to 52 ppm in few water samples in area during premonsoon period while it is observed in a range of 78 ppm to 130 ppm with an average of 104 ppm during postmonsoon period.

Chloride (Cl^{-}):

Chlorides that are highly soluble with most of the naturally occurring cations and are not precipitated, sedimented and cannot be removed biologically in treatment of the wastes. The water having higher concentration of chloride does not have any toxic effect on man. The large amount of chloride effect corrosively on metal pipes and is harmful to plant life. It produces a salty taste at 250-500 ppm level.

The concentration of chloride ranges in between 136.3 ppm to 1238.2 ppm with an average of 499.41 ppm during premonsoon period and it ranges from 266.96ppm to 1363.20 ppm with an average of 536.34 ppm during postmonsoon period. It shows an increase during postmonsoon due to less rainfall and negligible recharge in the study area. The higher concentrations are recorded at Idgah bus stand and M.S. Colony during premonsoon and postmonsoon periods respectively. The minimum amount of chloride is found in the water samples of Dayalbagh and Swamibagh. The major sources of chloride in groundwater are seepage from sewage, industrial effluents, and rainfall. According to I.S.I. (1983) the highest desirable limit of chloride is 250 ppm and maximum permissible limit of chloride is 1000 ppm.

Sulphate (SO_4^{2-}):

Sulphate combining with metals gives the permanent hardness of water and requires suitable treatment for different uses. The major sources of sulphate are different rocks containing sulphate minerals, rainwater and wastewater from domestic and industrial uses.

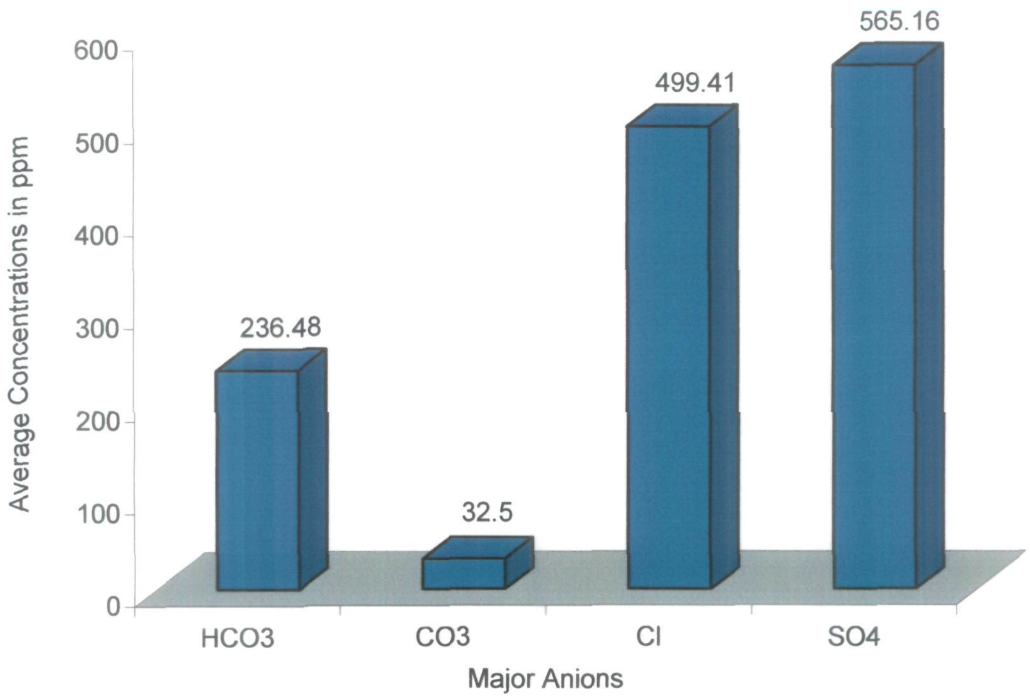


Fig.6.10: Bar graph showing average concentrations of Major Anions during premonsoon period (May-2004)

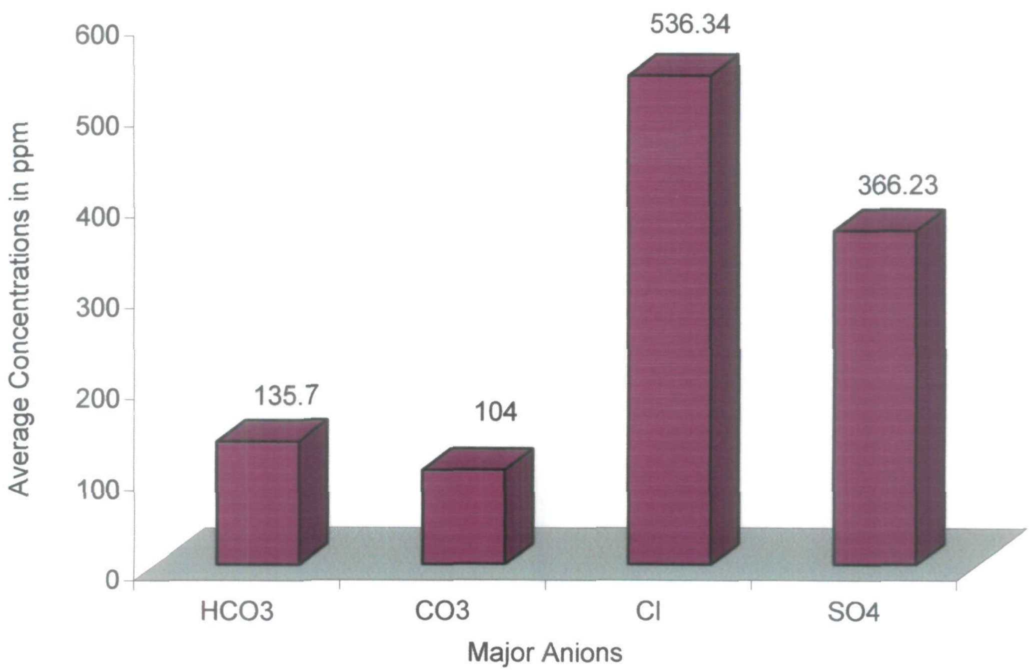


Fig.6.11: Bar graph showing average concentrations of Major Anions during postmonsoon period (Nov.-2004)

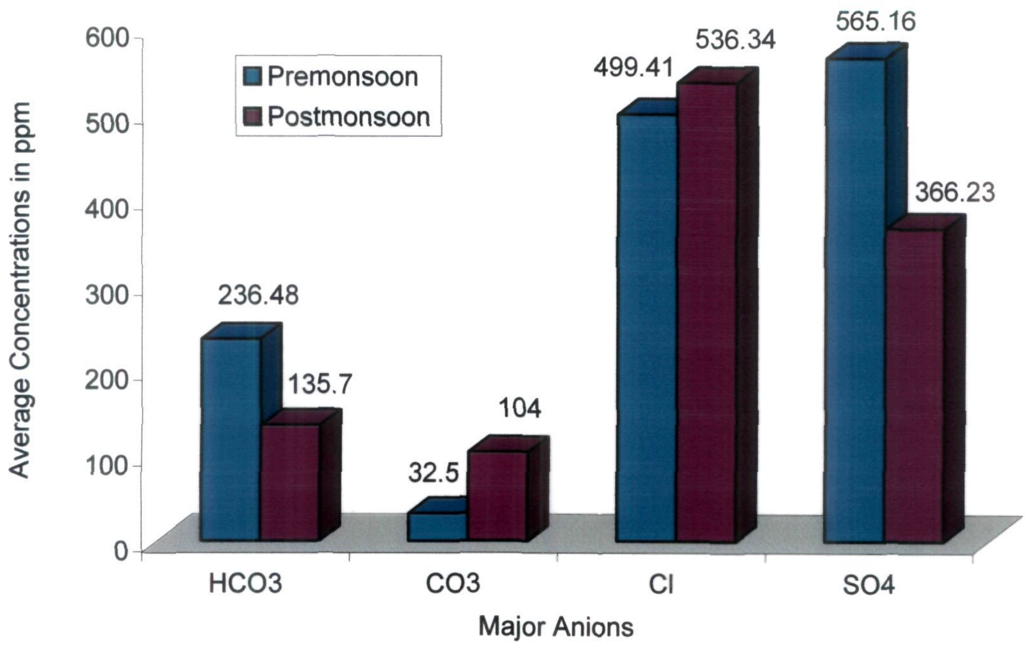


Fig.6.12: Comparision bar graph showing average concentrations of Major Anions during premonsoon and postmonsoon periods,2004

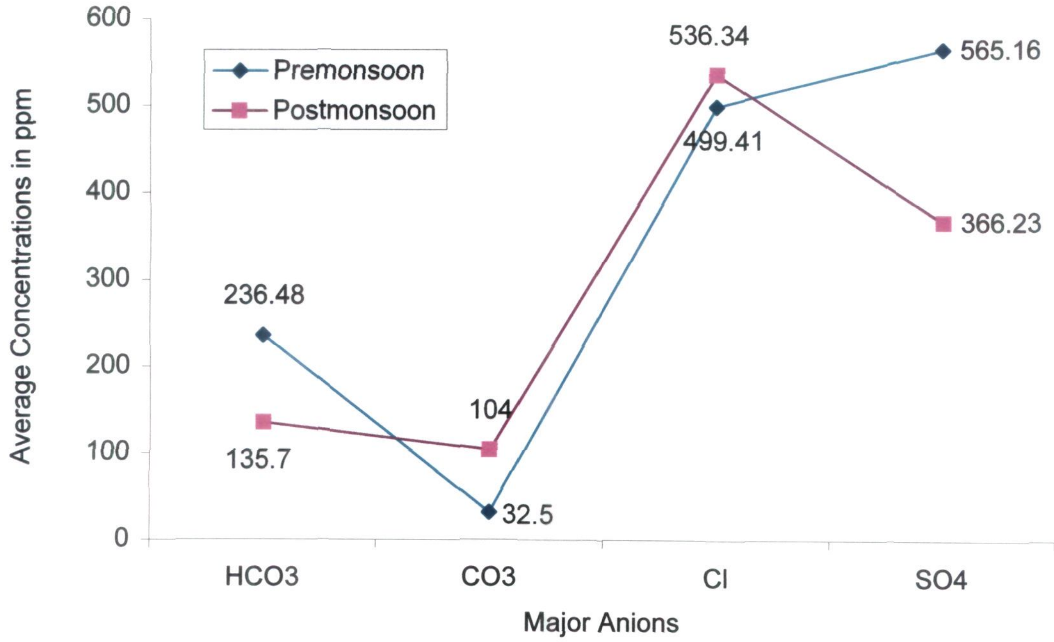


Fig.6.13: Comparision line graph showing average concentrations of Major Anions during premonsoon and postmonsoon periods,2004

In the study area, the concentration of sulphate ranges from 162.95 ppm to 1096.23 ppm with an average of 565.16 ppm in the groundwater samples during premonsoon period. The highest concentration is observed as 1096.25 ppm at Mamu Bhana Ghatia and the lowest concentration is recorded as 162.95 ppm at Charbagh of Shahganj area during premonsoon period.

During postmonsoon period the concentration of sulphate is in range the groundwater. Higher concentrations are recorded as 990.06 ppm and 964.55 ppm at Mamu Bhanja Ghatia and Mantola Thana area respectively. The lowest concentration is observed as 51.02 ppm at Chipitola of Rakabganj during this period.

6.8 TRACE ELEMENTS:

Trace elements include copper, zinc, chromium, manganese, nickel, iron and cobalt that have been analysed in the water samples of study area. The hydrochemical data of water samples for trace elements are given in Appendix-III and Appendix-IV during premonsoon and postmonsoon periods respectively.

Copper (Cu):

Copper in natural waters results in higher concentration due to pollution. It is used with sulphate as a pesticide and also separately as an algaecide. The natural source of copper includes the weathering of sulphide ores. The sources of copper that enhance the concentration in water include mining wastes, industrial effluents from electroplating units, textiles, paints, pumping equipments and pesticides. Copper is one of the essential elements for human body and the daily requirement is about 12 ppm for an adult.

The concentration of copper in the groundwater of the study area ranges from 0.0001ppm to 0.0161 ppm with an average of 0.006 ppm during premonsoon period. It ranges in between 0.0009 ppm to 0.531 ppm during postmonsoon period with an average value of 0.082 ppm. Copper concentrations are lower than the maximum permissible limit of 0.05–1.5 ppm prescribed by I.S.I. (1983). Copper has toxic effect on human body if concentration is below the desirable limit. High intake may result in damage to the liver. It is also involved in haemoglobin synthesis, connective tissue development and normal function of central nervous system. Copper deficiency is linked with anemia, diarrhoea, demineralization of bone etc. Wilson disease has been associated with abnormal copper metabolism.

Zinc (Zn):

Zinc is an essential and beneficial element for human bodies. The higher concentrations above 5 ppm cause bitter taste and opalescence in alkaline waters. Zinc plays an important role in enzymes and many enzymatic functions, protein synthesis and carbohydrate metabolism (Taylor and Demayo, 1980). It is also responsible for cell division and growth. Zinc concentration for adult varies from 1.4 to 3 gm (Underwood, 1971). The deficiency of zinc in human body results in infantilism, impaired wound healing and several other diseases.

The major sources of zinc concentration in water are the deterioration of galvanized iron and dezincification of brass beside industrial wastes. Natural sources of zinc are sulphide and carbonate ores. The sources of atmospheric zinc pollution include smelter, iron and steel manufacturing processes, combustion of coal and oil etc.

The concentration of zinc in groundwater of the study area during premonsoon period ranges from 0.032 ppm to 2.472 ppm with an average of 0.863 ppm. Higher concentrations are recorded at M.S. Colony of Idgah area and Dayalbagh as 2.472 ppm and 2.38 ppm respectively.

During postmonsoon period, the zinc concentration is in range of 0.0295 ppm to 0.795 ppm with an average of 0.328 ppm. The highest concentration is observed as 0.795 ppm in Mantola Thana area. According to the I.S.I. (1983) and W.H.O. (1984), the maximum desirable limit for zinc concentration is 5 ppm to 15 ppm.

Iron (Fe):

Iron is a common constituent of salts and rocks. The major sources of Iron in water are igneous rocks and sulphide ores of sedimentary and metamorphic rocks. It is derived from weathering of ferruginous minerals of these rocks. Other sources include effluents of industries manufacturing iron or steel and units in which iron is used as a raw material.

The concentration of iron in the study area ranges in between 0.034 ppm to 0.667 ppm with an average of 0.274 ppm during premonsoon period whereas it ranges from 0.025 ppm to 0.538 ppm during postmonsoon period with an average of 0.192 ppm. Higher concentrations are observed as 0.667 ppm and 0.538 ppm at Idgah bus stand and Dayalbagh during premonsoon and postmonsoon periods respectively. The maximum permissible limit for concentration of iron is 0.01ppm to 1.0 ppm according to I.S.I. (1983). The water of the area has the concentration of iron within the permissible limit.

Iron is essential for man. It is controlled in the human body mostly in the small intestine where both absorption and excretion take place. When iron is present in higher concentrations, it imparts bitter taste and inky flavor.

Manganese (Mn):

Manganese is an essential element for nutrition of man. Its deficiency may inhibit growth, disrupt the nervous system and interfere with reproduction functions (McWeely et al., 1979). The important sources of manganese are soils and sedimentary and metamorphic rocks. The concentration of manganese in groundwater is usually low due to gee-chemical controls. It is absorbed on the clays, organic matters, hydrated iron oxides, and silicates etc. Water pollution of manganese is due to industrial effluents particularly industries manufacturing iron and steel.

Manganese concentration is ranging in between 0.0.12 ppm and 0.426 ppm during premonsoon period with an average of 0.053 ppm. The highest concentration is observed as 0.426 ppm in Lajpat Kunj area.

During postmonsoon period, the concentration ranges from 0.021 ppm to 0.274 ppm with the average of 0.099 and shows the highest concentration than the premonsoon period. It may be due to less rainfall and negligible recharge of the aquifers in the area. According to the I.S.I. (1983), the maximum permissible limit for the concentration of manganese is 0.1 ppm to 0.5 ppm. Higher concentration of manganese is toxic and may cause manganism, a disease of central nervous system involving neurological disorder, with the result, there may be irritability, difficulty in walking, speech disturbances etc. (Mena et al., 1967).

Chromium (Cr):

Chromium is a toxic element. Hexavalent chromium (Cr^{+6}) is much more toxic than trivalent chromium (Cr^{+3}) but has no nutritional value. Cr^{+6} may be absorbed by ingestion through the skin and by inhalation and corrosion. Sign of toxicity by these elements include hemorrhage of the gastrointestinal tract after ingestion, ulceration of the nasal septum and cancer of respiratory tract from inhalation and cutaneous injury upon dermal exposure (National Academy of Science, 1974).

The concentration of chromium in the groundwater of the study area ranges from 0.005 ppm to 0.033 ppm with an average of 0.017 ppm during premonsoon period. It ranges between 0.165 ppm to 0.833 ppm during postmonsoon period with an average value of 0.484 ppm. The highest concentration is recorded as 0.033 ppm at Mantola area during premonsoon period while it is in higher concentration as 0.833 ppm in Mamu Bhanja Ghatia during postmonsoon period.

Nickel (Ni):

Toxicity of nickel or nickel salt through oral intake is low. Nickel salts exert their action mainly by gastrointestinal irritation and not by inherent toxicity (Schroeder et al., 1961).

The groundwater of the area has nickel in the range of 0.009 ppm to 0.03 ppm during premonsoon period. It is in the range of 0.086 ppm to 0.321 ppm in the water samples of the area during postmonsoon period. The maximum concentration is observed as 0.03 ppm at Idgah bus stand during premonsoon period while it is in higher concentration at Teela Mattamal of Tajganj area during postmonsoon period where it is 0.321 ppm. The average values of nickel are 0.017 ppm and 0.484 ppm during premonsoon and postmonsoon periods respectively.

Cobalt (Co):

The concentration of cobalt in the groundwater samples of the area is with in the range of 0.013 ppm to 0.042 ppm during premonsoon period. The maximum concentration is observed as 0.042 ppm at Mantola Thana during this period. The minimum concentration is recorded at Charbagh of Shahganj area during premonsoon period where it is 0.013 ppm. The average concentration is 0.026 ppm during this period.

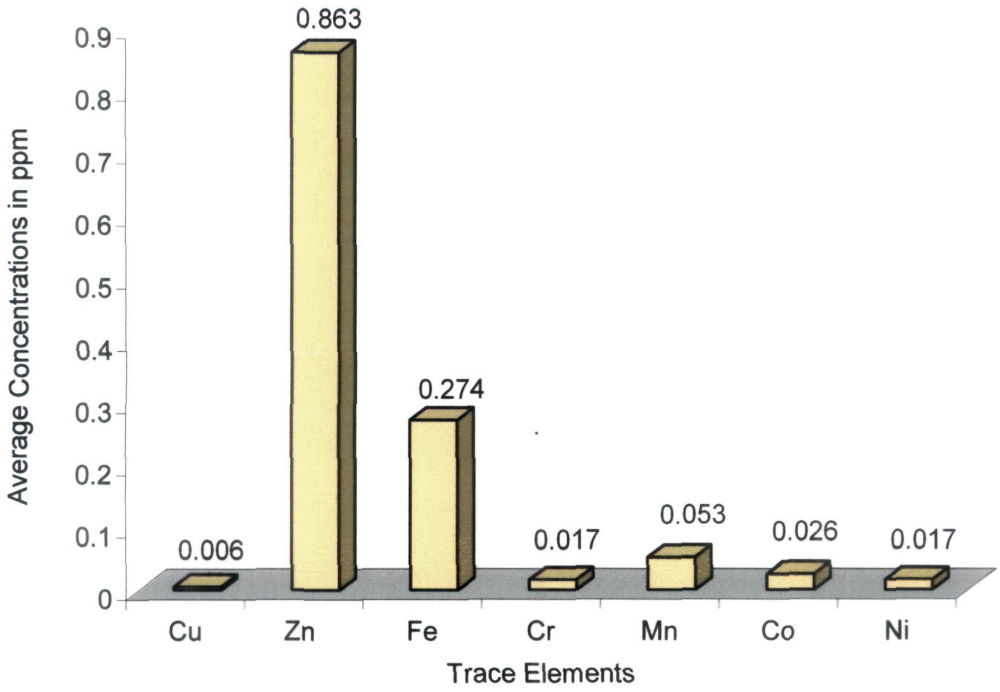


Fig.6.14: Bar graph showing average concentrations of Trace Elements during premonsoon period (May-2004)

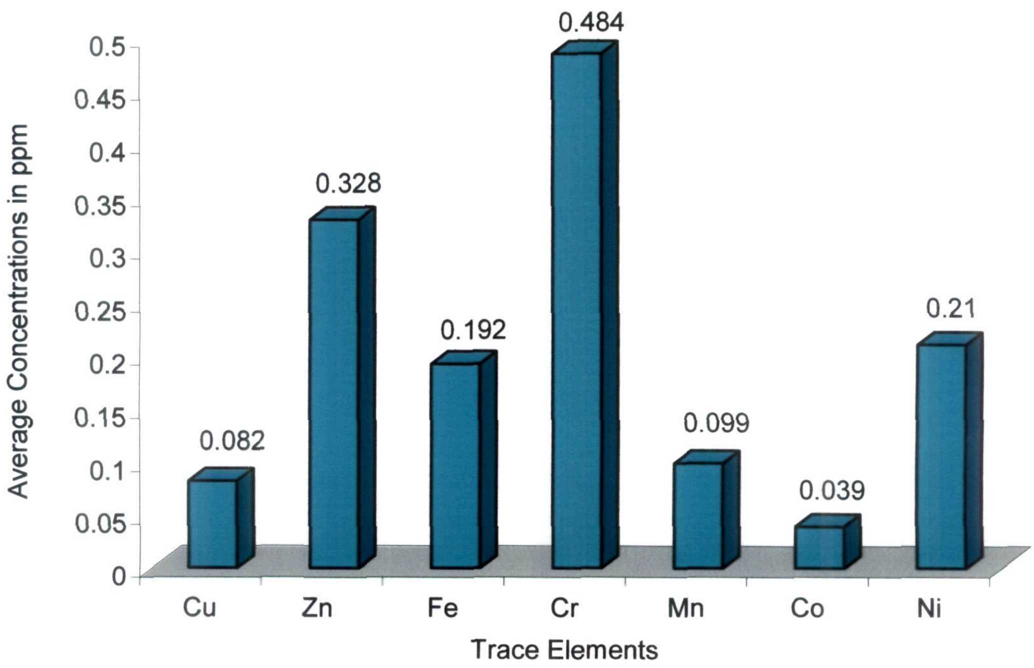


Fig.6.15: Bar graph showing average concentrations of Trace Elements during postmonsoon period (Nov.-2004)

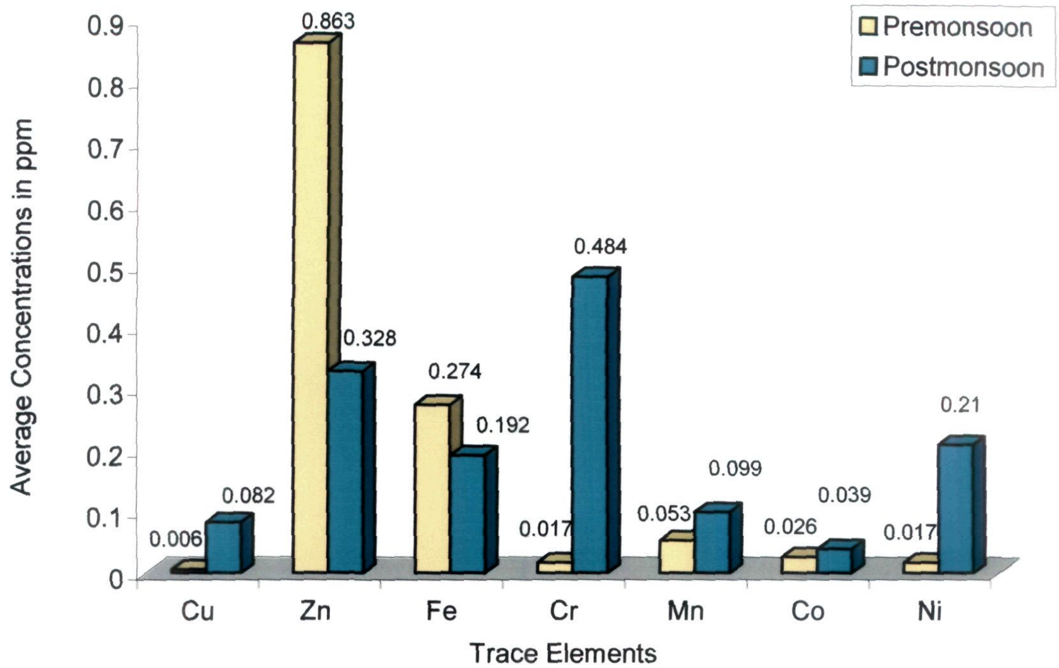


Fig.6.16: Comparision bar graph showing average concentrations of Trace Elements during premonsoon and postmonsoon periods,2004

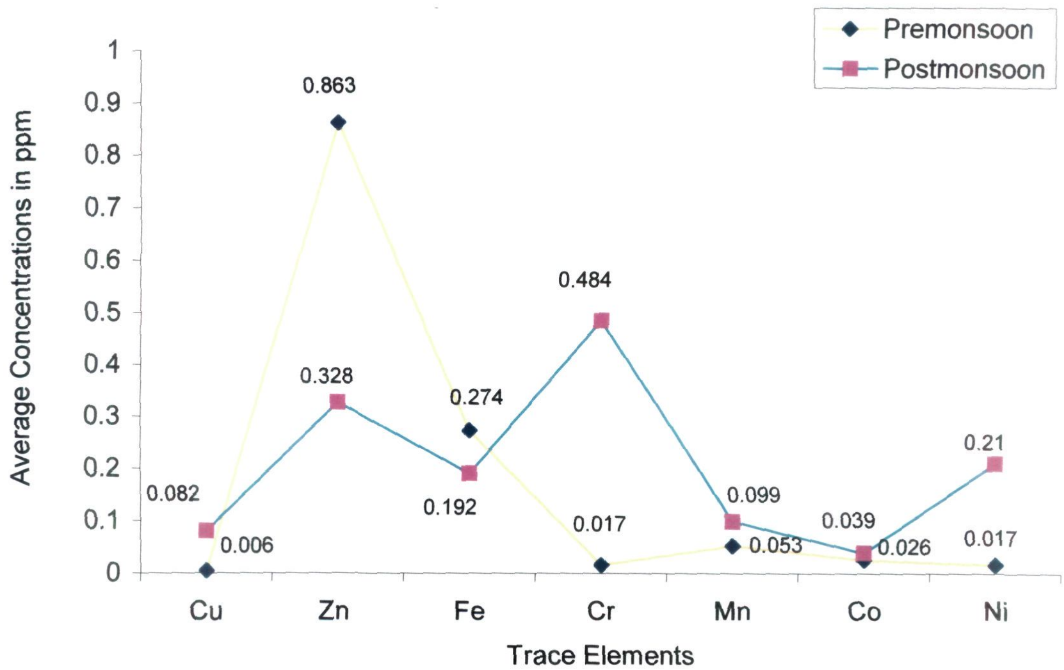


Fig.6.17: Comparision line graph showing average concentrations of Trace Elements during premonsoon and postmonsoon periods,2004

During postmonsoon period, the concentration of cobalt ranges from 0.015 ppm to 0.091 ppm with an average of 0.039 ppm in the groundwater samples of the study area. The maximum concentration is recorded as 0.091 ppm at Teela Mattamal of Tajganj area. The lower concentrations are recorded at Chipitola and Kazipada of Rakabganj area, Mantola Thana area and Purani Mandi area during this period.

Table 6.5: Range of different parameters in the groundwater samples of the study area during premonsoon and postmonsoon periods, 2004

Parameters	Concentration Range (ppm)	
	Premonsoon	Postmonsoon
pH	7.1 – 8.8	7.3 – 8.9
E.C. (μs/cm)	700 – 4000	900 – 3300
T.D.S.	448 – 2560	576 – 2112
Hardness	96 – 920	16 – 112
Ca^{2+}	8.01 – 384.76	12.82 – 246.89
Mg^{2+}	9.74 – 168.6	1.94 – 145.21
Na^{+}	257.14 – 114.23	255 – 1138.82
K^{+}	0.48 – 80.48	3.58 – 87.69
HCO_3^-	156 – 388	39 – 364
CO_3^{--}	26 – 52	78 – 130
Cl^-	136.3 – 1238.2	266.9 – 1363.20
SO_4^{2-}	162.95 – 1096.23	51.02 – 990.06
Cu	0.0001 – 0.0161	0.009 – 0.531
Zn	0.032 – 2.472	0.0295 – 0.795
Fe	0.034 – 0.667	0.025 – 0.538
Mn	0.012 – 0.426	0.021 – 0.274
Cr	0.005 – 0.033	0.165 – 0.833
Ni	0.009 – 0.03	0.086 – 0.321
Co	0.013 – 0.042	0.015 – 0.091

6.9 GRAPHICAL METHODS:

An important task in groundwater investigation is compilation and presentation of chemical data in a convenient manner for visual inspection. For this purpose, graphic representations are useful for display, comparing analyses and for emphasizing similarities and differences. A variety of graphic techniques have been developed for showing the hydrochemical data. In the present study, bar graph, line graph and trilinear diagram have been used for the presentation of the results of chemical analysis.

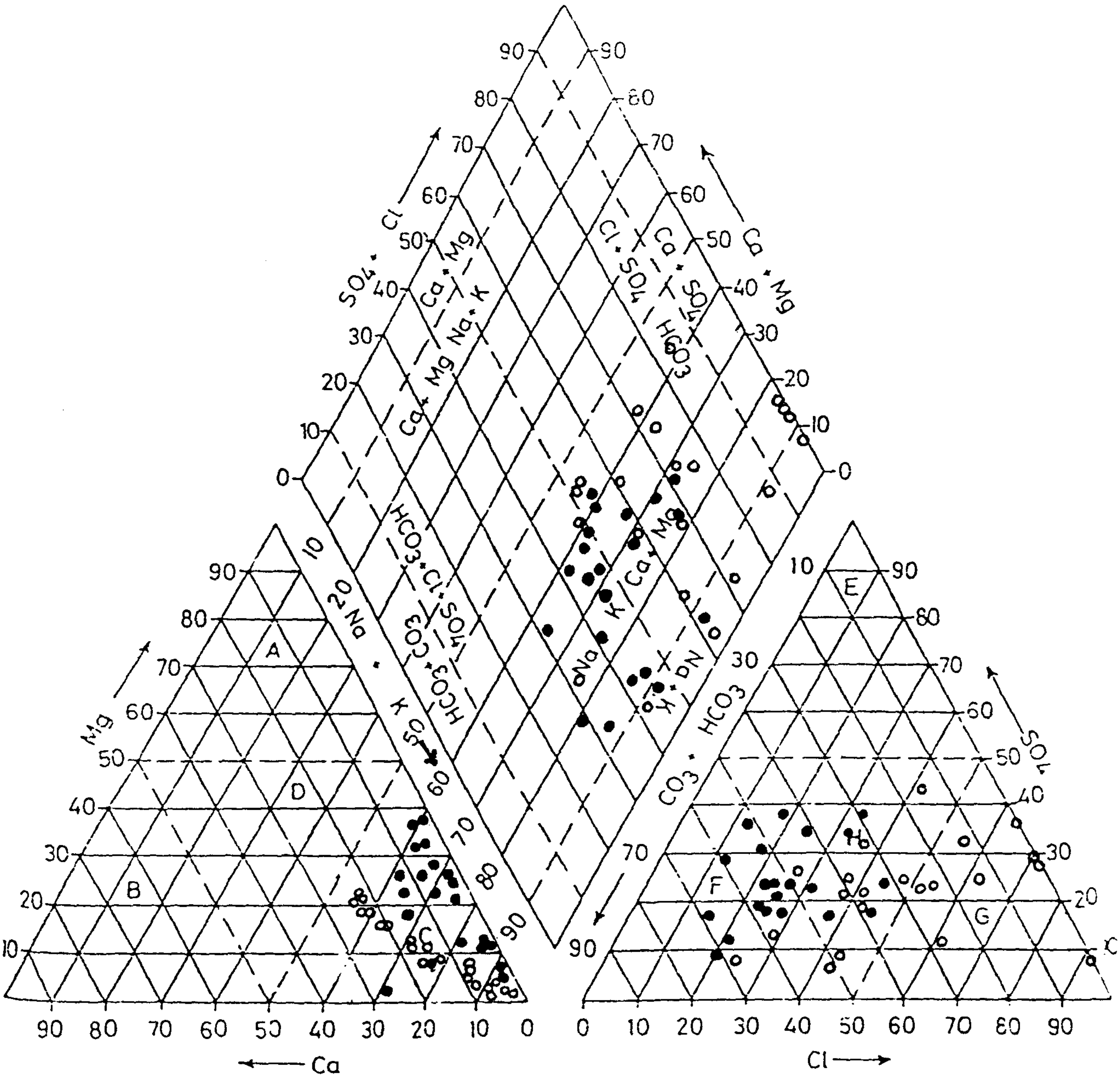
Bar diagram is the simplest and widely used for representing chemical quality of water. The results of analysis of chemical quality of groundwater have been plotted on bar-diagram. Vertical bar represents the average concentration as well as the comparison of avérage concentration of major ions and trace elements during premonsoon and premonsoon periods respectively.

Line graphs have also been used to represent the comparison of average concentration of physical and chemical parameters, major ions and trace elements during premonsoon and postmonsoon periods respectively.

The bar diagrams are all easy to construct and provide quick visual comparison of individual chemical analysis but they are not convenient for graphic presentation of large numbers of analyses. For this purpose a diagram developed by Piper (1944) is in common use to show chemical character of groundwater. The trilinear diagram represents the concentrations as percentages. In the triangular field at the lower left, the percentage reacting values of the three-cation groups (Ca^{++}, Mg^{++}, Na^{+}) are plotted as single point according to conventional trilinear coordinates. Likewise three anion groups (HCO_3^-, SO_4^{--}, Cl^-) are plotted at the lower right. The central diamond shaped field is used to show the overall chemical character of the groundwater by single point plotting, which is at intersection of rays projected from the plottings of cations and anions.

6.10 HYDROCHEMCIAL FACIES:

In order to represent water composition in a convenient manner by identifiable groups, Back (1961, 1966), and Morgan and Winner (1962) have developed the concept of hydrochemicai facies. Hydrochemical facies are distinct zones that have cation and anion concentrations describable within defined composition categories (Allan and Cherry, 1979). According to Back (1961) the term hydrochemical facies is used to describe the bodies of groundwater in an aquifer that differ in their



Cations Facies

A. Magnisium type
B. Calcium type
C. Sodium or Potassium type
D. No Dominent type

Anions Facies

E. Sulphate type
F. Bicarbonate type
G. Chloride type
H. No Dominent type

Fig. 6.18: Piper trilinear diagram showing chemical character of groundwater during premonsoon and postmonsoon periods, 2004 (● premonsoon, o postmonsoon)

chemical composition. The facies are a function of lithology, solution kinetics and flow pattern of the aquifer (Back, 1966).

The percent values of cations and anions were plotted on trilinear diagram as suggested by Morgan and Winner (1962) and Back (1966) in order to designate hydrochemical facies of the study area. The plotting of analytical results shows that sodium or potassium is the dominant facies among the cations. Most of samples fall in the sodium or potassium type of the cation facies both during premonsoon and postmonsoon period, while the samples fall in bicarbonate and no dominant type of anion facies during premonsoon and chloride and no dominant type of anion facies during postmonsoon. Some samples also fall in the bicarbonate type of anion facies during postmonsoon period.

6.11 WATER QUALITY STANDARDS:

The term standard applies to any definite principle or measure established by limiting concentration of constituents in waters which ensure the safe use of water and safeguard the environment. Polluted water is hardly of any use for most purposes. It cannot be utilized for drinking because of its inherent health risk. The quality of water also interferes with the aesthetic and economic pursuits of water by affecting the aquatic life. However, the water, which is not suitable for drinking may be good for irrigation, or water unsuitable for irrigation may be quite suitable for industrial cooling or fish growth. Thus it can be seen that each use of water has its own limits on the degree of pollution it can accept.

Every use of water requires a certain minimum quality of water with regard to the presence of dissolved and suspended materials of both chemical and biological nature. The interpretation of a chemical, physical and biological analysis is highly subjective matter and is not possible to have single water quality criteria that can have universal application. Therefore, certain accepted standards have been adopted while interpreting the chemical analyses result of water in relation to its use. Water quality criteria is considered as specific requirement on which a decision or judgement to support a particular use will be based.

Water Quality Standards For Domestic Uses:

In view of the direct consumption of water by human beings, the domestic water supply is considered to be the most critical use of water. Drinking water standards are based on the presence of objectionable tastes, odours, colours and the presence of substances with adverse physiological effects. Various national and international organizations like Indian Council of Medical Research (1975), Indian Standard Institution (1983) and World Health Organization (1971, 1984) have formulated certain drinking water standards. The main objective of these guidelines is to safeguard the health of the people and to combat pollution hazards.

The hydrochemical data of the water samples of the study area show that the concentrations of hardness, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^- are within the permissible limit of W.H.O. (1984) and I.S.I. (1983) at most places. But at few places, they were found above the maximum permissible limit of W.H.O. (1984) and I.S.I. (1983). The values of E.C., pH and T.D.S. were found higher at most places in the study area. Groundwater is therefore, characterized by higher extent of salinization. Overall, groundwater is brackish, moderately hard to hard and alkaline in nature.

The concentration of certain trace elements like Cu, Zn, Mn, Cr, Fe are within the permissible limit of the drinking water standards of W.H.O. (1984) and I.S.I. (1983). Trace elements are most harmful and toxic pollutants because of their non-biodegradable nature and their potential to cause adverse effects on human health.

Table 6.6. Water quality criteria for public water supply

Characteristics	**ISI – 1983**		**WHO – 1984**	
	Highest desirable (ppm)	**Maximum permissible (ppm)**	**Highest desirable (ppm)**	**Maximum permissible (ppm)**
pH	7 – 8.5	6.5 – 9.2	7 – 8.5	6.5 – 9.2
Total Hardness	300	600	100	500
Calcium	75	200	75	200
Magnesium	30	100	30	150
Bicarbonate	--	--	--	--
Nitrate	45	45	45	45
Chloride	250	1000	200	600
Sulphate	150	400	200	400
Aluminum	--	--	--	--
Iron	0.3	1.5	0.1	1.0
Manganese	0.1	0.5	0.05	0.5
Copper	0.05	1.5	0.05	1.5
Zinc	5	15	5	15
Arsenic	0.05	No relaxation	--	0.05
Mercury	0.001	-do-	--	0.01
Cadmium	0.01	-do-	--	0.001
Lead	0.05	-do-	--	0.1
Chromium	0.05	-do-	--	--
Selenium	0.01	-do-	--	0.01

Table 6.7. Pathological effects of heavy metal water pollutants

S.No.	Metals	Pathological effects on Man
1.	Lead	Vomiting, anaemia, loss of appetite, damage of brain, liver and kidney
2.	Cadmium	Diarrhoea, growth retardation, kidney damage, bone deformation, testicular atrophy, anaemia, injury of central nervous system and liver, hypertension.
3.	Arsenic	Disturbed peripheral circulation, disturbances, liver cirrhosis, hyperkerolosis, lung cancer, kidney damage.
4.	Copper	Hypertension, uremia, coma, sporadic fever.
5.	Zinc	Vomiting, renal damage, cramps.
6.	Hexavalent chromium	Nephritis, gastrointestinal ulceration, disease in central nervous system, cancer.
7.	Cobalt	Diarrhoea, low blood pressure, paralysis bone deformation.
8.	Mercury	Abdominal pain, headache, diarrhoea, chest pain, hemolysis.

Water Quality Standards for Irrigation:

Utilization of groundwater for irrigational purpose depends on many factors such as texture and composition of soil, type of crop, climate, irrigational practices and finally chemical quality of groundwater. With regard to the quality of water for irrigation, the major parameters of concern are salinity denoted by dissolved solids and conductivity, potentially toxic trace elements and herbicides. Besides, the presence of sodium is also an important parameter, the excess quantity of which can deteriorate the soils. High value of sodium may also damage the sensitive crops because of sodium phototoxicity.

In order to evaluate the suitability of groundwater of the study area for agricultural uses, relative proportion of sodium to other cations and Sodium Adsorption Ratio (SAR) have been determined. The concentration of sodium is important in classifying irrigation water because sodium reacts with soil to reduce its permeability (Todd, 1980). Soils containing a large concentration of sodium render it unsuitable for plant growth.

Sodium content is usually expressed in terms of percent sodium, which is shown in Appendix-I and Appendix-II respectively of premonsoon and postmonsoon period. It is calculated by following formula.

$$\% \, Na = \frac{(Na + K)}{Ca + Mg + Na + K} 100$$

where all ionic concentrations are expressed in milli-equivalent per litre (epm).

Sodium ions have a tendency to be adsorbed by soil collides. Increase of sodium ion content in water beyond 50% replaces the ions like Ca and Mg in soil by Base Exchange. Percent sodium upto 50% is acceptable for irrigation use above which alkalization steadily increases. This will support little or no plant growth. The following classification based on percent sodium and electrical conductivity of water for irrigation has been given by Wilcox (1955).

Table 6.8 Quality classification of water for irrigation (after Wilcox, 1955)

S.No.	Water Class	% Na	E.C.
1.	Excellent	< 20	< 250
2.	Good	20 – 40	250 – 750
3.	Permissible	40 – 60	750 – 2000
4.	Doubtful	60 – 80	2000 – 3000
5.	Unsuitable	> 80	> 3000

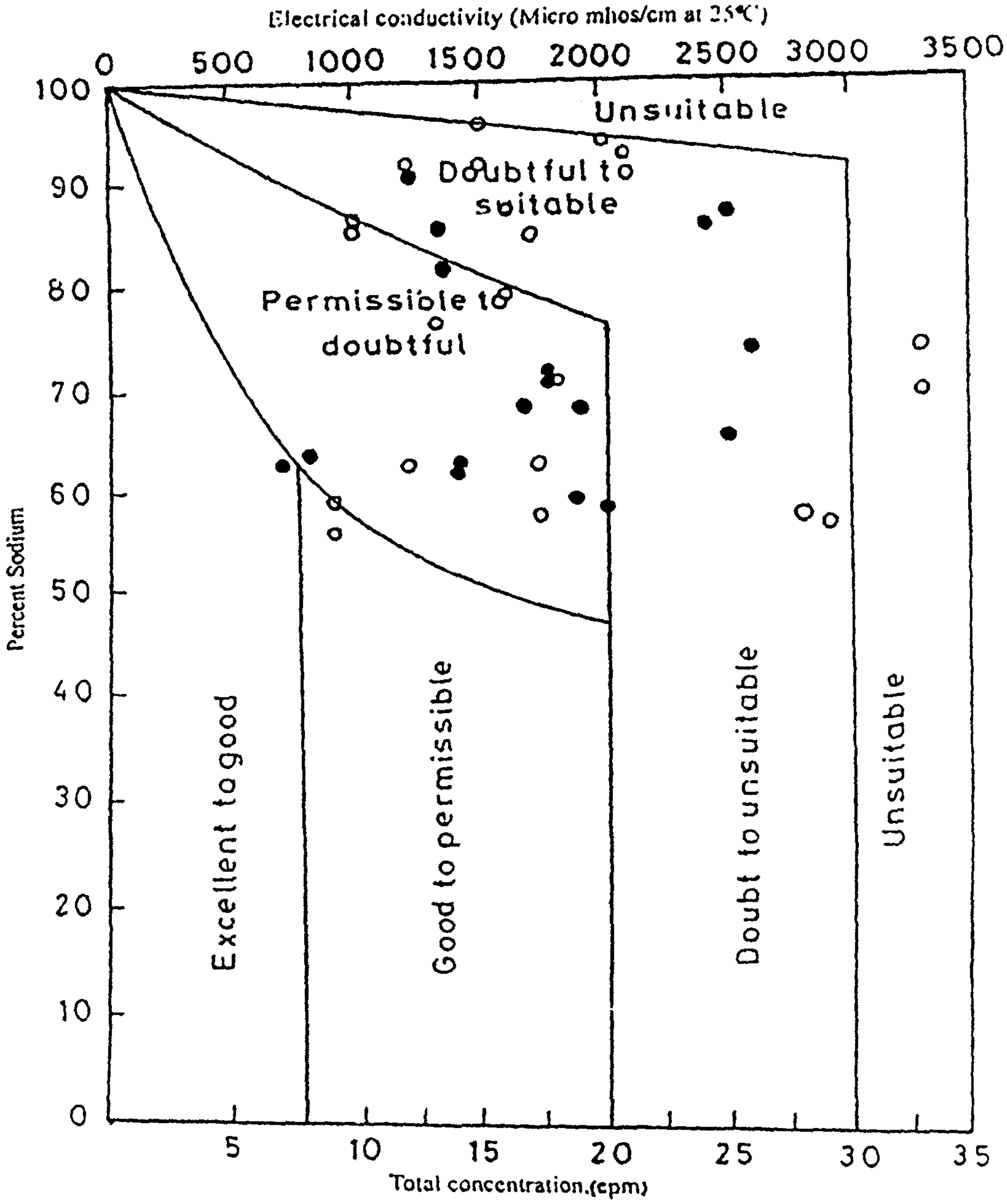


Fig. 6.19: Plot of Sodium Percent vs. Electrical conductivity (after Wilcox, 1955) showing classification of groundwater for irrigation use during premonsoon and postmonsoon periods, 2004 (• premonsoon, o postmonsoon)

The sodium percentage values in the study area range from 60.02 to 93.07 with an average value of 73.27 during premonsoon period, while it is ranging between 56.06 and 96.37 with an average of 76.31 during postmonsoon period. The maximum sodium percentages were recorded at Idgah bus stand and Kotala House of Khandari area.

Plot of sodium percent vs. electrical conductivity gives an idea about the irrigation suitability of water. Plot of sodium percent shows that the samples are permissible to doubtful and doubtful to suitable for irrigation purpose both during premonsoon and postmonsoon periods.

Sodium Adsorption Ratio (SAR) and Salinity Hazards:

Sodium Adsorption Ratio (SAR) can better assess suitability of water for agricultural purposes because of its direct relation to the adsorption of sodium by soil. Sodium Adsorption Ratio is the relative proportion of sodium to calcium and magnesium and is calculated by the following expression:

$$\mathrm{SAR} = \frac{\mathrm{Na}}{\sqrt{(\mathrm{Ca} + \mathrm{Mg})/2}}$$

where all ionic concentrations are expressed in mili-equivalent per litre (epm). Sodium Adsorption Ratio is usually calculated due to the direct relation of sodium to adsorption by soil. The salinity hazard increases as the soils become finer grained and aridity increases resulting in the concentration of salts in the soil that may require periodical leaching. Excessive sodium content in water is unsuitable for soil containing exchangeable calcium and magnesium. The T.D.S., expressed in terms of E.C. and Sodium Adsorption Ratio form the basis for classification of water for irrigation purposes. The quality classification of irrigation water as suggested by U.S. Salinity Laboratory (1954) is given in Table-6.9.

Table 6.9: Quality classification of irrigation water (after U.S.S.L., 1954)

Salinity Hazards (E.C. in μS/cm)	**Alkali Hazards (SAR)**	**Water class**
< 250 (C_1)	< 10 (S_1)	Excellent
250 – 750 (C_2)	10 – 18 (S_2)	Good
750- 2250 (C_3)	18 – 26 (S_3)	Moderate
> 2250 (C_4)	> 26 (S_4)	Poor

The study area experiences the value of Sodium Adsorption Ratio (SAR), ranges from 6.17 to 34.38 with an average of 13.82 during premonsoon and it ranges from 5.39 to 38.04 with an average of 15.2 during postmonsoon period.

U.S. salinity diagram indicates the salinity hazard as well as sodium hazard. The diagram shows that the samples are of the category C3-S2, C3-S3, C3-S4, and C4-S3, C4-S4, where the C3 and C4 are the class of salinity hazard that indicate the high and very high category for it

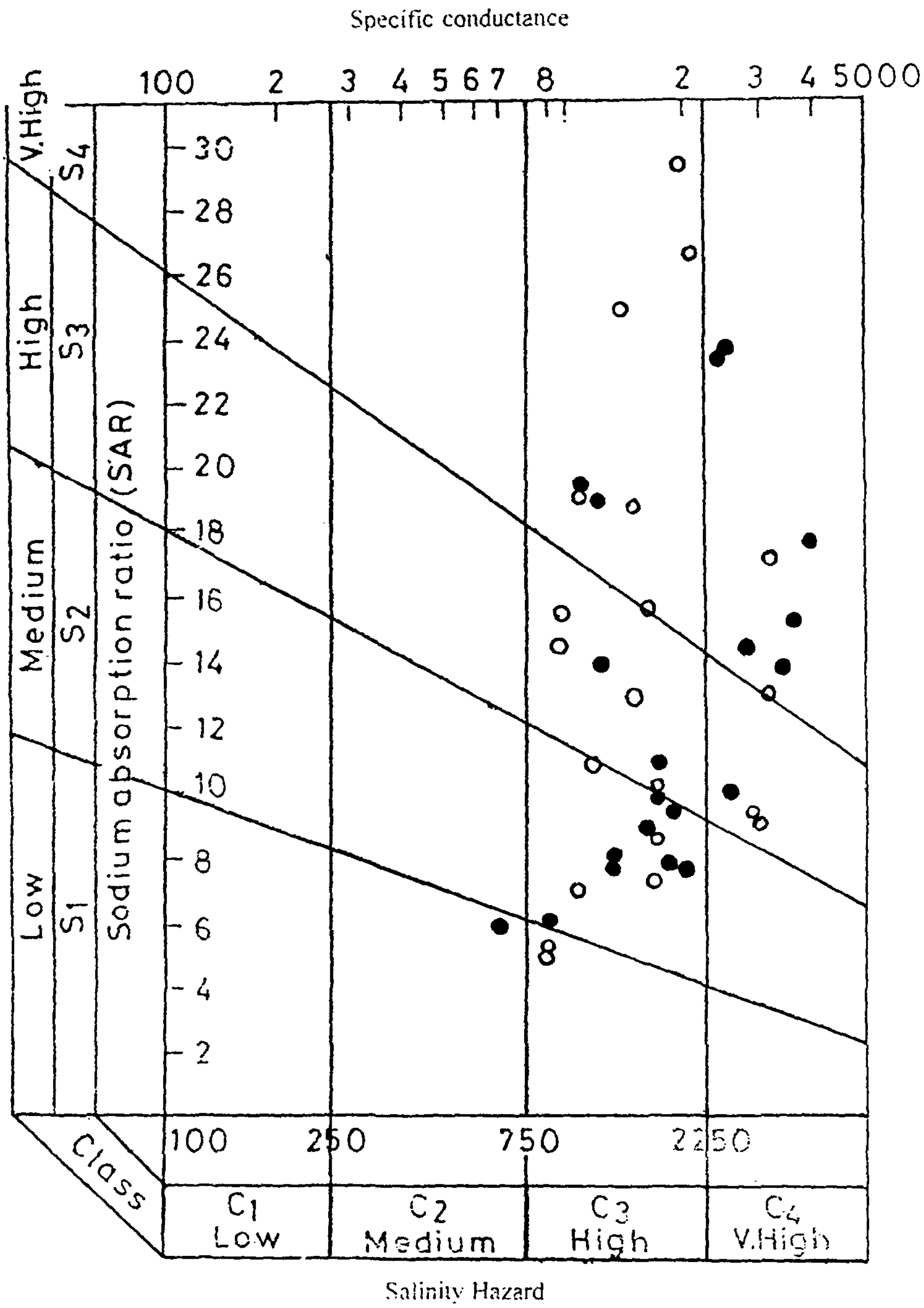


Fig. 6.20: U.S. salinity diagram for classification of irrigation water during premonsoon and postmonsoon periods, 2004 (• premonsoon, o postmonsoon)

respectively and, S2, S3 and S4 indicate the medium, high and very high category respectively for the class of sodium hazard. Goel (1997) has suggested the criteria based on different chemical constituents and SAR values for irrigational purpose, is given in the following tables:

Table 6.10: Suitability of water with different constituents for irrigation.

Class of water	TDS (ppm)	Sulphate (ppm)	Chloride (ppm)	% Na	E.C. (μS/cm)	Suitability for irrigation
I	0-700	0-192	0-142	0-60	0-750	Excellent to good for irrigation
II	700-2000	192-480	142-355	60-75	750-2250	Good to injurious, suitable only with permeable soil and moderate leaching harmful to sensitive crops.
III	>2000	>480	>355	>75	>22-50	Unfit for irrigation

Table 6.11: Suitability of water for irrigation with different values of SAR

SAR	Suitability for irrigation
0-10	Suitable for all types of crops and all types of soils except for those crops which are highly sensitive to sodium.
10-18	Suitable for coarse textured or organic soil with good permeability. Relatively unsuitable in fine textured soil.
18-26	Harmful for almost all types of soil. Require good drainage, high leaching and gypsum addition.
>26	Unsuitable for irrigation.

While comparing the data of the present investigation with the above classification, it is seen that most of the groundwater samples in the study area falls in II class of water quality and is suitable for all types of crops and all types of soils except for those which are highly sensitive to sodium.

Ayers and Branson (1975) and Federal Water Pollution Control Federation, U.S.A. (1968) have proposed tolerance limit of trace elements for irrigation and is given in the Table- 6.12

Table 6.12: Trace elements tolerance limit (mg/L) of irrigation water as proposed by FWPCF (1968) and Ayers and Branson (1975)

Trace elements	Water use (FWPCF, 1968)		Water use (Ayers & Branson, 1975)	
	Continuous	Short term in fine textured soil	Continuous	Short term in fine textured soil
Copper	0.2	5.0	0.2	5.0
Iron	-	-	5.0	15.0
Manganese	2. 0	5.0	0.2	10.0
Zinc	5.0	10.0	2.0	10.0
Cadmium	0.005	0.05	0.01	0.05
Lead	5.0	10.0	5.0	10.0
Chromium	5.0	0.05	0.1	1.0
Lithium	5.0	5.0	2.5	2.5

While comparing the content of trace elements in groundwater of the study area with standard limits, it is found that the concentrations of trace elements are within the permissible limit. But most of the groundwater samples are deficient in concentration of trace elements.

Chapter-7

Summary and Conclusion

SUMMARY AND CONCLUSION

Environment is a surrounding; external conditions influencing development or growth of people, animals and plants. Environmental degradation which is the overall lowering of environmental qualities because of adverse changes brought in by human activities in the basic structure of the component of the environment that adversely affect all biological communities, in general. Environmental degradation leaves direct impact on the ecology causing ecological imbalance due to marked reduction in the ecosystem and ecological diversity. Environmental degradation and environmental pollution are synonym but environmental pollution means lowering of the quality of environment at local scale caused exclusively by human activities. Environmental pollution includes water pollution, soil pollution and air pollution but water pollution is the main concerned due to its direct impact on the human causing different diseases and require the frequent attention and assessment.

The quality of water is vital concern for mankind and it provides sustenance to plants and animals, constitutes habitat for aquatic organism and meets important agricultural, domestic and industrial needs. Water pollution is a state of deviation from pure condition and its limited volume, fluctuation in its level and degradation of water quality are the critical problems for most of the land surface. Waste disposal and improper management of water projects have led to unfortunate results, including the spread of various diseases such as typhoid, jaundice, cholera, diarrhoea, dysentery, dehydration, abdominal illness and the most dangerous cancer.

Agra is the one of the famous metropolitan city of Uttar Pradesh and is known for Tajmahal. It is situated on the banks of river Yamuna and has more than 300 large and small-scale industries including dyeing, leather, metals, food and beverage industries etc. The study area lies at latitude 27°10'N and longitude 78°5'E and covers about 65 sq. kms. area.

Geomorphologically the area is divided into three units; present flood plain, old flood plain and upland of marginal alluvium. The study area experiences the severe heat during summer in the month of June when highest temperature is around 44°C and the minimum temperature during winter in the month of Dec.-Feb. is around 7.5°C. The general direction of the natural drainage is toward river Yamuna that enters the area from North and following the meandering courses passes out of the area in the SSE direction. The study area is a part of Ganga-Yamuna interfluves. The thick pile of sediments comprising sands of various grades, silt and clay intercalated with *kankar*. Groundwater in the study area occurs both under confined and unconfined conditions. The river Yamuna is perennial and effluent in nature.

Different meta-sedimentary, sedimentary rocks and Quaternary Alluvium form the geological framework of the study area. These formations belong to Bhilwara Super Group, Delhi Super Group, Vindhyan Super Group and Quaternary Alluvium. Vindhyan Super Group is dominating exposed and overlain by Quaternary Alluvium, comprising admixture of gravel, sand, silt and *kankar* in varying proportion.

The groundwater in the area occurs both under confined and unconfined conditions, which is recharged mainly by rainfall during southwest monsoon period from July to September. The general direction of groundwater flow is from NNW to SSE. Depth to water level varies widely. According to UP Jal Nigam Agra (2004), aquifer performing tests concluded on selected handpumps show that saturated aquifer have yielded 13 L.P.M. to 15 L.P.M. and the water level stables at 13 m to 21 m in 2004, which was 14 L.P.M. to 16 L.P.M. and 12 m to 18.5 m respectively in 2001. In premonsoon period (May 2004), the depth of water table ranges from 10.5 m to 23.5 m below ground level while in postmonsoon period (Nov. 2004), the depth to water table ranges from 9 m to 21.3 m below ground level. The groundwater level fluctuation in the study area ranges from 0.5 m to 5.5 m in the year 2004.

Geoenvironmental appraisal of any region is important for planning its future development and utilizing its natural resources. The geoenvironmental hazards of the study area are mainly associated with the inherent geological and geomorphological setting and exogenic process of land degradation of anthropogenic nature. Major geoenvironmental problems observed in the study area are soil alkalinization, soil erosion, water logging floods, river aggradation, groundwater salinity, sand mining and water pollution.

The potential factor, which is very common and adverse for life of the study area, is groundwater pollution. The groundwater of Agra city is very much polluted. Most of the samples from dug wells, hand pumps, bore wells, tap water etc. are of poor quality on account of bacteriological contamination. High contamination of nitrate, chloride and phosphate have been reported besides recording its severity within a radius of about 200 m from their respective septic tanks in the study area. It is observed from the analysis of groundwater of study area that concentration of Cr, Ni, Mn, Cu etc. are with in the permissible limits of drinking. The common chemical pollutants of both surface and groundwater are sulphate, nitrate, phosphate, chloride, sodium and calcium ions.

The impact of rapid urbanization and industrialization have introduced three alarming problems in the hydrogeological regimen. i.e. less groundwater recharge, greater run-off causing flood problem and quality deterioration of groundwater. The sewage systems installed for domestic, industrial and surface water drainage, increase the amount of water borne toxic and bacteriological wastes in response to the growth in population and industries related to tannery. Further, the changes in the water quality are intimately linked with the consequences of the increase in building density.

Detailed information about various chemical characteristic, temporal changes in water quality and variation in chemical characteristics with increase in depth with other features, would be useful in planning for control and abatement of water pollution to safeguard the health of the people of the area. The systematic study of the chemical and physical parameters of water quality of the groundwater has been made to find out the extent of pollution with various major ions and trace elements.

The physical and chemical parameters taken in account during the study are Electrical Conductivity (E.C.), pH, Total Dissolved Solids (T.D.S.) and Hardness. The maximum concentrations of these parameters in the groundwater samples are 4000 μs/cm for E.C., 8.8 for pH, 2560 ppm for T.D.S. and 920 ppm for Hardness during premonsoon period. The higher concentrations of these parameters during postmonsoon period are 3300 μs/cm for E.C., 8.9 for pH, 2112 ppm for T.D.S. and 112 ppm for Hardness. The average values of these parameters during premonsoon period are 2128.57 μs/cm, 7.8, 1362.28 ppm and 479.66 ppm while the average values during postmonsoon period are 1771.4 μs/cm, 7.8, 1133.7 ppm and 58.09 ppm for E.C., pH, T.D.S. and Hardness respectively.

The maximum concentrations of sodium, potassium, calcium and magnesium in groundwater samples are 1114.3 ppm; 80.48 ppm, 384.76 ppm and 163.6 ppm respectively during premonsoon period. The higher concentrations of these cations during postmonsoon period are 1138.8 ppm, 87.69 ppm, 246.89 ppm and 145.21 ppm respectively. The higher values of these cations are probably due to both intensive industrialization and agricultural activities in the area. The concentrations of major cations exceed the maximum permissible limit prescribed by W.H.O. (1984) in some groundwater samples. The average values of these cations are 650.61 ppm, 23.02 ppm, 59.28 ppm and 87.09 ppm respectively during premonsoon period and 552.7 ppm, 24.8 ppm, 94.96 ppm and 45.9 ppm respectively during postmonsoon period.

The maximum concentration of anions such as HCO_3^-, CO_3^{--}, Cl^- and SO_4^{--} in groundwater samples are 338 ppm, 52 ppm, 1238.2 ppm and 1096.23 ppm respectively during premonsoon period while these are at high concentration during postmonsoon period as 364 ppm, 139 ppm, 1363.20 ppm and 990.06 ppm respectively. Carbonate is generally absent in most of the samples both during premonsoon and postmonsoon periods, while HCO_3^- is absent in some of the samples during postmonsoon period. The average values of these anions during premonsoon period are 236.48 ppm, 32.5 ppm, 499.41 ppm and 565.16 ppm respectively, while it is 135.7 ppm, 104 ppm, 536.34 ppm and 366.23 ppm respectively during postmonsoon period.

The results of chemical analysis of trace elements show that some of the constituents present in groundwater samples are in concentration much higher than the tolerance limit prescribed by I.S.I. (1983) and W.H.O. (1984). The dumping of raw sewage and industrial effluents are the major sources of trace elements in the study area. The concentrations of trace elements in water samples range as 0.0001 to 0.016 ppm for copper, 0.032 to 2.472 ppm for zinc, 0.034 to 0.667 ppm for iron, 0.005 to 0.033 ppm for chromium, 0.012 to 0.426 ppm for manganese, 0.013 to 0.042 ppm for cobalt and 0.009 to 0.03 ppm for nickel during premonsoon period. The water samples have these elements during postmonsoon period in the range between 0.009 to 0.53 ppm for copper, 0.0295 to 0.795 ppm for zinc, 0.025 to 0.538 ppm for iron, 0.165 to 0.833 ppm for chromium, 0.021 to 0.274 ppm for manganese, 0.015 to 0.091 ppm for cobalt and 0.086 to 0.321 ppm for nickel. The average concentration of these elements during premonsoon period are 0.006, 0.863, 0.274, 0.017, 0.053, 0.026 and 0.017 ppm for copper, zinc, iron, chromium, manganese, cobalt and nickel respectively. The trace elements have the average concentration as 0.082, 0.328, 0.192, 0.484, 0.099, 0.039 and 0.21 ppm respectively during postmonsoon period.

In the present study, bar graph, line graph and trilinear diagram have been used for the presentation of the results of chemical analysis.

Bar diagram represents the average concentrations as well as the comparison of average concentrations of major ions and trace elements during premonsoon and premonsoon periods respectively.

Line graphs have also been used to represent the comparison of average concentrations of physical and chemical parameters, major ions and trace elements during premonsoon and postmonsoon periods respectively.

Piper trilinear diagram is plotted to know about the chemical character of groundwater samples. Most of samples fall in the sodium or potassium type of the cation facies both during premonsoon and postmonsoon periods, while the samples fall in bicarbonate and no dominant type of anion facies during premonsoon period and chloride and no dominant type of anion facies during postmonsoon period. Some samples also fall in the bicarbonate type of anion facies during postmonsoon period.

The hydrochemical data of the water samples of the study area show that the concentrations of hardness, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^- are within the permissible limit of W.H.O. (1984) and I.S.I. (1983) at most places. But at few places, they were found above the maximum permissible limit of W.H.O. (1984) and I.S.I. (1983). The values of E.C., pH and T.D.S. were found higher at most places in the study area. Groundwater is therefore, characterized by higher extent of salinization. Overall, groundwater is brackish, moderately hard to hard and alkaline in nature.

The concentration of certain trace elements like Cu, Zn, Mn, Cr, Fe are within the permissible limit of the drinking water standards of W.H.O. (1984) and I.S.I. (1983). Trace elements are most harmful and toxic pollutants because of their non-biodegradable nature and their potential to cause adverse effects on human health.

The sodium percentage values in the study area range from 60.02 to 93.07 with an average value of 73.27 during premonsoon period, while it is ranging between 56.06 and 96.37 with an average of 76.31 during postmonsoon period. The maximum sodium percentages were recorded at Idgah bus stand and Kotala House of Khandari area.

Plot of sodium percent vs. electrical conductivity gives an idea about the irrigation suitability of water. Plot of sodium percent shows that the samples are permissible to doubtful and doubtful to suitable for irrigation purpose both during premonsoon and postmonsoon periods.

The study area experiences the value of Sodium Adsorption Ratio (SAR), ranges from 6.17 to 34.38 with an average of 13.82 during premonsoon period and it ranges from 5.39 to 38.04 with an average of 15.2 during postmonsoon period.

U.S. salinity diagram indicates the salinity hazard as well as sodium hazard. The diagram shows that the samples are of the category C3-S2, C3-S3, C3-S4, and C4-S3, C4-S4.

While comparing the data of the present investigation with the water classification for irrigation suitability, it is seen that most of the groundwater samples in the study area falls in II class of water quality and is suitable for all types of crops and all types of soils except for those which are highly sensitive to sodium and comparing the content of trace elements in groundwater of the study area with standard limits, it is found that the concentrations of trace elements are within the permissible limit.

But most of the groundwater samples are deficient in concentration of trace elements.

7.1 RECOMMENDATIONS:

The environment degradation in the study area has taken place due to different types of pollution made by the people. The water pollution is the major problem of the area, which is due to the indiscriminate disposal of industrial wastes on the land and surface water channels. High content of pollutants has been assessed in the groundwater of the area from the present study and deserve the frequent attention and observation. As groundwater is the major source of drinking water and industrial supply of the area, suitable measures are necessary to safeguard the health of the people of the area.

It is recommended that before releasing the effluents in the river, SAR most significantly be reduced with decolorization which can be achieved by extraction of the caustic with existing technology. This process leads to considerable reduction in pH and sodium concentration. Continuous monitoring and remedial measures should be implemented to reduce the metal content in the industrial effluents to avoid further enhancement of pollutants in the water of the area. Stabilization of ecosystem is the most reliable way to control water pollution, which involves reduction in waste input and removal of biomass and aeration.

Installing proper waste treatment and disposal system can reduce pollution loads from industrial and urban centres. The colours from the effluents can be removed by treating the effluents with lime, which not only removes the colour but also reduces suspended solids. T.D.S. may be reduced by using some chemical or natural coagulants.

Reutilization and cycling of waste is another way to control water pollution. Urban waste could be recycled to generate cheaper fuels, gas and electricity. Various impurities in water like suspended solids, dissolved solids, bacteria and other chemical and biological pollutants can be reduced by different treatment methods such as adsorption, electrodialysis, filtration, chlorination, precipitation, ion exchange and reverse-osmosis. Water for drinking purpose should be tapped from deeper aquifers.

Environmental implication of all development projects including land use planning, new industries and irrigation scheme should be well examined before implementation. To create better environment and to protect the ecosystem from further degradation, government should pass legislation for strict compliance of the industry to treat their effluents at their owns cost and it should be implemented.

7.2 PERSPECTIVE PLANNING:

The entire groundwater potential available from the study area cannot be utilized due to its salinity and deteriorated water quality for human consumption. However, the annual groundwater draft from the study area is 1,779 ha m which is about 83 per cent of groundwater resource and could not meet the total demand of water supply to the study area. The position will further worsen due to increasing population and industrialization in future. Under the above circumstances, Water Works Authority and city planners have to depend mainly on this water bodies, i.e. Yamuna river and Kitham reservoir. To overcome this situation following recommendations have been made.

(i) Barrage on Yamuna river was recommended at Agra and Gokul and accepted in principle by the government of Uttar Pradesh, but it could not be materialized due to shortage of funds. Necessary steps must be taken for the construction of barrage to augment the water supply. This would recharge the entire aquifer system of the area, and will also help in improving the groundwater quality. Water resources development activity including perspective planning of its development may have to be finalized.

(ii) Presently, Kitham reservoir water is being utilized to ease the scarcity situation in the study area. Some more such reservoirs should be planned in the ravines, banks of Yamuna river in up stream to recharge the aquifer system and to improve the quality of groundwater. Similar reservoirs should also be developed along Agra canal to meet out the near crisis condition of water availability.

(iii) Exposed unlined liquid refuse carrying drains, which form a network in the study area, should be lined as per specification to check direct infiltration of contaminants to the groundwater repository. Also, leakage from septic tanks, sewer, raw sewage disposal on land surface should be judiciously checked. In addition, uncontrolled dumping of domestic refuse and municipal wastes on fields and topographic lows should be stopped to save the water resources from further pollution.

(iv) Water from Middle Ganga Canal (Mat branch) is to be diverted to feed the Yamuna river to ease the crisis of water supply of Agra during lean period. It should be regularized and legalized since, as per National Water Policy, the first priority of water is for drinking purpose. Necessary modifications must be made in this regard.

(v) The old handpumps and open wells should be repaired and put to use for water supply development programme.

(vi) Community participation is imperative so that water quality protection be further strengthened by educating common masses on location specific environmental impacts on groundwater quality vis-à-vis quantitative monitoring systems, environmental consequences on health hazards, etc. In right earnest, dissemination of such information shall be encouraged at all levels of participatory agencies. The concept of environmental degradation and groundwater pollution menace, in other words aptly needs demonstration amongst the masses.

(vii) For sustenance of ameliorative measures in the scenario, need based action plans are to be formulated and accordingly tailored, and additional thrust to be given in promoting awareness at all levels to combat adverse environmental impact of pollution of groundwater resources due to anthropogenic causes. Adoption of such constructive approach would be one of the earnest remarkability for sustaining healthy socio-cultural fabric through a multi-disciplinary drive to generate awareness amongst the citizens and civic authorities of the metropolis as also to discuss options for an appropriate cooperative instrument to enable sharing of experience and exchange informations related to the subject for motivation as a whole.

(viii) Agra is a 'World Heritage City' and to save it from water crisis, two parallel water supply systems should be developed and planned, one for safe drinking water and other for domestic water requirements. The electric supply, which is very poor and due to which the pumping units of Agra Jal Sansthan are not running to their full capacity, should be improved by all means.

References

REFERENCES

Ajmal, M., Khan, M.A., Nomani, A.A. (1985): Distribution of heavy metals in water and sediments of selected sites of Yamuna river (India), Environ. Mont. Assess. 5: 205-214.

American Public Health Association (1975): Standard methods for analysis, 14th ed., New York.

Anon (1975): "Manual of standards of quality of drinking water supplies" 2nd edition, Special Report Series No. 44, Indian Council of Medical Research, New Delhi.

APHA (1992): Standard Methods for Examination of water and wastewater, Washington, D.C., USA.

Arnold, E., Greenberg et al. (1992): Standard methods for the examination of water and waste water, pp. 3-73.

Bagde, S.J. (1984): Environmental quality and pollutional assessment, national conference on pollution study in Major Indian river basin.

Basu, A.K. (1983): Groundwater pollution and its control. Proceedings Seminar on groundwater for rural and urban water supply. INC., International Association of Hydrogeologists, Calcutta.

Berg, J.W. and Burbank, F. (1972): Geochemical environment in relation to health and disease. Ann. N.Y. Academy of Science, 199, pp. 249-264.

Bhargava, D.S. (1977): Water quality in three typical rivers in U.P. – Ganga, Yamuna and Kali, thesis presented to IIT, Kanpur.

Bhu-Jal News April – June (1990): Groundwater pollution due to industrial effluents, pp. 1-11.

Bower, V.M. (1976): Aspects of heavy toxicity in fresh water, pp. 59-79.

C.G.W.B. (1982): Evaluation of aquifer parameters. A Manual, Central Groundwater Board, Ministry of Irrigation, Govt. of India, pp. 183.

Chandra, V. Satya (1980): A status report of R&D work done in India. Toxic metals in environment, published by Industrial Toxicology Research Centre, Lucknow, India.

Chatterji, G.C. (1967): Groundwater resources of India, Bull. G.S.I., Ser., B. No. 260, pp. 60.

Chisholm, J.J. (1971): Lead poisoning Scient. Am., V. 224, pp. 15-23.

Cohen, J.M. et al. (1969): Taste threshold concentrations of metals in drinking water, Jour. Amer. Water Works Association, V. 52, pp. 660.

Collins, W.D. (1923): Graphic representation of water analysis, India and England Chem. Vol. 15, pp. 394.

Craun, G.F. and Mc Cabe, L.J. (1975): Problems associated with metals in drinking water, Journal American Water Works Association, 67, pp. 593-599.

Dakshini, K.M.M. and Soni, J.K. (1979): Water quality of sewage drains entering Yamuna in Delhi, Indian Jour. Environ. Health, 21, ipp. 354-360.

Dayal, G., Singh, R.P. and Kapoor, R.C. (1991): Groundwater pollution by solid wastes a case study, Poll. Res., Vol. 10(2), pp. 111-116.

De, A.K. (1995): Environmental Chemistry, 3rd edition New Age International (P) Limited, Publishers pp. 167-280.

Drinking Water and Health (1980), Vol. 3, National Research Council, Washington, D.C.

Environmental Protection Agency (1973): Water quality Criteria, E.P.A. Publishers, R.3-73-033, pp. 594.

Fetter, C.W. (1988): Applied Hydrogeology 2nd ed. Merril Publ. Company, Ohio, pp. 529.

Garg, D.K., Pant, A.B., Manju, A.B. and Goyal, R.N. (1990): Seasonal variations in groundwater quality in Roorkee city, IJEP, Vol. 10(9), pp. 673-676.

Geddes, A. (1960): The Alluvial Morphology of the Indogangetic Plains, Trans. Inst. Br. Geogr. Pp. 253-275.

Ghosh, G.K. (1992): Environmental pollution – A scientific dimension, pp. 121-124.

Goel, R.S. (1996): Environmental Impact Assessment for water resources projects. Proceedings symposium on Earth Sciences in Environmental Assessment, Lucknow, April 1996, GSI, spl. Pub. 48, Vol. 2, pp. 247-258.

Gopal, D., Singh, R.P. (1989): Heavy metal contamination of groundwater in Agra city, Proceedings Nat. Acad. Sci. India, 61(A) IV: 569-572.

Handa, B.K. (1974): Standard methods of collection and analysis of water samp. Data and interpretation of water analysis data, min. of agr. Tech. Manual., pp. 363.

Handa, B.K. (1975): Groundwater pollution in India; National Symp. on Hydrology, Univ. of Roorkee, pp. 34-39.

Handa, B.K. (1976): Modern methods of water analysis, Tech. man. C.G.W.B., Ministry of Agr. And Irrigation, pp. 1-404.

Handa, B.K. (1983): Hydrochemical investigations in the alluvial formation of U.P. in the phreatic zone, vol. 1, pp. 305.

Indian Council of Medical Research (1957): Manual of Standards of Quality for drinking water supplies, I.C.M.R., New Delhi, 2nd edition.

Indian Standard Institution (1983): Drinking water standards, Table-1, Substances and Characteristics affecting the acceptability of water for domestic use.

Jana, M.M. (1991): Environmental degradation and developmental strategies in India, pp. 57-81.

Kacker, Y.P., Lal, R., Kumar A., Singh, B. and Das, J. (1987): Chemistry of groundwater in Northern Western India, Rep. CGWB.

Kannan, N. and Rajeshkharan, N. (1991): Correlations of water quality parameters of prnting industry effluents in Sivakasi, Indian J. Environ. Hlth, Vol. 33(3): pp. 330-335.

Karanth, K.R. (1987): Groundwater Assessment Development and Management, Mc Graw Hill Publishing Co. Ltd., New Delhi, pp. 720.

Karanth, K.R. (1987): Groundwater assessment, development and management, pp. 255-267.

Kaur, A., Pallah, B.S., Sahota, G.P.S. and Sahota, H.S. (1992): Seasonal variability of chemical parameters in drinking water from shallow aquifers, IJEP, Vol. 12(6), pp. 409-415.

Khan, A.M. (1989): Report on the selection of tube well sites for augmenting domestic water supply to Kheria Air Field, Agra District, Uttar Pradesh, Rep. CGWB.

Khan, S.K., Rao, C.U. and Bandhopadhyaya, M. (1994): Characteristics of leachates from solid wastes, Indian J. Environ. Hlth. Vol. 36(4), pp. 248-250.

Khopkar, S.M. (1993): Environmental pollution analysis, pp. 34-36.

Khoshoo, T.N. (1991): Environmental concerns and strategies, pp. 86-90.

Khurshid, S. (1984): Industrial pollution – A case study in union territory of Delhi, National Conf. on pollution, St. in major Indian River Basins, pp. 34-43.

Krishnan, M.S. (1968): Geology of India and Burma, Sixth ed. C.B.S.Publishers, India, pp. 536.

Kumar, A. (1983): Pollution of natural waters by lead in U.P.

Kumar, A. and Prasad, U. (1990): Environmental protection and industrial development, Vol. 3, pp. 8.

Mishra, S.G. and Prasad, D. (1983): Pollution through solid waste, pp. 23-29.

Mukherjee, S. and Rai, J.N. (1996): Impact of urbanization on groundwater of Agra Metropolitan City, Uttar Pradesh. Proceedings symposium on Earth Sciences in Environmental Assessment and Management, Lucknow, April 1996, GSI, spl. Pub. No. 48, Vol. 1, pp. 213-221.

National Academy of Science (1977): Drinking water and health, Washington, D.C., pp. 279-283.

Nigam, N. and Rastogi, R. (1998): Significance of nitrate in groundwater for domestic use in Agra Division, Uttar Pradesh, Bhu-Jal News (Comm.).

Nigam, N., Sodhi, T.N., Prakash, R., Malhotra, P. and Singh, K. (1998): Bhu-Jal News, Vol. 13, No. 1&2, June 1998, pp. 33-35.

Panda, N. and Singh, B.C. (1996): Trace elements in drinking water from different sources in port city of Paradeep, IJEP, Vol. 16(11), pp. 824-827.

Parker, C.R. (1972): Water analysis by atomic absorption spectroscopy, Varian Tech. Pvt. Ltd., Australia.

Patterson, J.B. (1971): Metal toxicity arising from industries, Tech. Bull. Ministry of Agriculture, pp. 193-207.

Prasad, D. and Gaur, H.S. (1992): Environmental pollution (water), pp. 13.

Raghunath, H.M. (1987): Groundwater second edition. Wiley Eastern Limited, pp. 563.

Rai, J.N. (1989): Report on the hydrogeological studies for pinpointing of well sites in the identified problems in villages of Agra District Uttar Pradesh, National Drinking Water Mission, Rep. CGWB.

Rainwater, F.H. and Thatcher, L.L. (1960): Methods for collection and analysis of water samples. U.S. Govt. Printing Office, Washington, D.C.

Rajmohan, N., Elango, L. and Elampooranam, T. (1997): Seasonal and spatial variation in magnesium and chloride concentrations in groundwater Nagai Quad-E-Milleth district in TN, IJEP, Vol. 17(6).

Ram, S., Misra, H.P., Zaidi, A and Baranwal, M. (1996): Groundwater pollution studies on Eastern Bank of Yamuna River, Delhi

Proceedings symposium of Earth Sciences in Environmental Assessment and Management, Lucknow, April 186, GSI, spl. Pub. 48, Vol. 1, pp. 197-201.

Rastogi, R. and Gaumat, M.M. (1990): Pollution of groundwater in Mathura district, U.P., Bhu-Jal News, Qut. Journal of C.g.W.B., Vol. 5, No. 2, pp. 49-51.

Saxena, A., Sharma, S. Kulshreshta, U.C. and Srivastava, S.S. (1991): Factors affecting alkaline nature of rain water in Agra (India). Indian Journal of Environmental Pollution, 74, pp. 129-138.

Singh, A. (1996): Strategic Environmental Assessment (SEA) as a tool for sustainable development, Proceedings symposium on Earth Sciences in Environmental Assessment, Lucknow April, 1996, GSI spl. Pub. 48, Vol. 2, pp. 219-228.

Singh, Charanjit et al. (1996): Toxicity of electroplating effluents, J. of Industrial Pollution Control, Vol. 12 (11), pp. 15-19.

Singh, M. (2001): Heavy metal in pollution in freshly deposited sediments of the Yamuna river: a case study from Agra and Delhi urban centers, India, International Journal of Earth Sciences, Environmental Geology, Vol. 40, No. 6, March 2001, pp. 664-671.

Singh, R.P., Chauhan, B.S. and Khan, B.Z. (1997): Groundwater and its pollution, Asian J. of Chemistry, Vol. 9(4), pp. 841-844.

Singh, R.P., Chauhan, B.S., Khan, B.Z. and Karr, A. (1998): Characteristics and groundwater pollution potential of solid waste Leachate. Asian J. of Chemistry, Vol. 10(4), pp. 824-827.

Singh, R.P., Chauhan, B.S., Swaroop D. and Yadav, Y.S. (2000): Seasonal variation in groundwater quality of Agra City, Indian Journal of Environmental Health, Vol. 42, No. 2, April 2000, pp. 59-69.

Sinha R.K. (1980-81): Geology and Geomorphology of a part of Yamuna Basin, Distt. Faridabad (Haryana), Ghaziabad (U.P.) and Delhi. Progress report for field season 1980-81, pp. 7-39.

Sinha, B.P.C. (1985): Progress report on systematic geohydrological investigation in the selected parts of hard rock and the adjacent alluvium of Agra, Mathura districts, U.P., Tech. Rep. GSI.

Taylor, G.C. (1959): Groundwater Provinces of India, Economic Geology, Vol. 54, pp. 683-697.

Todd, D.K. (1980): Groundwater Hydrology, 2nd ed. John Wley and Sons, pp. 535.

Trivedi, R.K. and Goel, P.K. (1984): Chemical and Biological Methods for water pollution studies, Environ. Publ. Karad, pp. 215.

U.P. Jal Nigam: Reports on completion plan of hand pumps in Agra city.

U.S.P.H.S. (1962): United States Public Health Service, Drinking Water Standards, Publication No. 956, U.S. Govt. Printing Office, Washington, D.C.

Wilcox, L.V. (1955): Classification and use of irrigation water U.S. Deptt. of Agri. Circ. 969, Washington, D.C. pp. 19.

World Health Organization (1984): Guidelines for drinking water quality, Vol. 1 and 2, Recommendations, W.H.O., Geneva.

Appendices

APPENDIX-I

Physicochemical parameters and hydrochemical data of the water samples (ppm) during premonsoon period (May- 2004)

Sl. No.	Sampling Locations	pH	E.C. (μmho/cm)	T.D.S.	Hardness	Ca	Mg	Na	K	HCO_3	CO_3	Cl	SO_4	SAR	%Na
1.	Lajpat Kunj	8.2	1400	896	600	67.33	105.25	462.85	8.29	208	-	383.40	441.95	8.21	63.08
2.	Bharatpur House	8.3	1400	896	580	35.27	119.87	451.42	4.39	234	-	374.80	353.06	8.14	62.96
3.	Chipitola	7.7	1900	1216	568	97.79	78.94	531.42	64.87	273	-	363.50	784.31	9.70	68.55
4.	Kazipada	8.3	1800	1152	540	22.44	117.92	600.00	66.82	234	-	369.20	1023.8	11.22	71.98
5.	Mamu Bhanja Ghatia	8.0	3800	2432	920	384.76	9.74	114.28	20.97	182	-	732.72	1096.2	15.33	71.02
6.	Mantola Thana	8.1	3700	2368	872	72.14	168.60	942.85	20.97	221	-	744.08	1007.3	13.88	70.41
7.	Charbagh	8.2	1300	832	260	33.06	42.88	531.42	4.39	234	52	261.28	162.95	14.35	81.73
8.	Sorokatra	8.8	1300	832	240	24.04	43.55	680.00	4.39	221	26	252.76	205.75	19.12	86.10
9.	Teela Mattamal	7.7	1900	1216	740	16.03	167.62	497.14	10.24	195	-	468.60	441.95	8.01	60.02
10.	Purani Mandi	7.4	2000	1280	696	22.44	155.93	474.28	10.24	169	-	482.80	306.15	7.81	59.97
11.	Hanuman Chauraha	7.8	2400	1536	360	25.65	72.11	1022.8	12.19	325	26	572.50	557.99	23.45	86.15

12.	Kotla House	7.3	2500	1600	296	20.84	59.44	931.42	11.21	299	26	511.20	562.10	23.56	87.34
13.	Swami Bagh	7.7	800	512	312	44.88	48.72	257.14	0.48	182	-	147.60	211.51	6.33	64.19
14.	Dayal Bagh	7.1	700	448	328	17.63	69.19	257.14	0.48	156	-	136.30	540.71	6.17	63.04
15.	Nunhai Chauraha	7.9	1800	1152	472	19.23	103.30	497.14	80.48	234	-	431.60	376.93	9.95	71.48
16.	Trans-Yamuna Colony	7.6	1700	1088	496	28.85	103.30	451.42	77.56	208	-	448.70	832.05	8.81	68.53
17.	Naubasta	7.9	2500	1600	728	72.14	133.51	634.28	14.14	338	-	528.20	688.02	10.22	65.73
18.	Telipada	7.8	2600	1664	604	41.68	121.82	817.14	16.09	312	-	545.20	296.28	14.45	74.83
19.	Idgah Bus Stand	7.1	400	2560	168	17.63	30.21	1022.9	20.00	286	-	1226.8	651.81	34.38	93.07
20.	M.S. Colony	7.4	4000	2560	192	173.14	58.47	1045.7	19.02	247	-	1238.2	915.17	17.55	77.38
21.	Samjay Place	8.1	1200	768	96	8.01	18.51	440.00	16.09	208	-	318.08	412.32	19.59	91.09
	Average	**7.8**	**2128.57**	**1362.3**	**479.66**	**59.28**	**87.09**	**650.61**	**23.02**	**236.48**	**32.5**	**499.41**	**565.16**	**13.82**	**73.27**

APPENDIX-II

Physicochemical parameters and hydrochemical data of the water samples (ppm) during postmonsoon period (Nov. -2004)

Sl. No.	Sampling Locations	pH	E.C. (μmho/cm)	T.D.S.	Hardness	Ca	Mg	Na	K	HCO_3	CO_3	Cl	SO_4	SAR	%Na
1.	Lajpat Kunj	7.9	1300	832	72	65.73	22.41	395.00	6.66	312	-	383.40	176.12	10.69	77.21
2.	Bharatpur House	8.2	1200	768	64	28.85	1.94	395.00	5.64	-	-	386.24	223.03	19.21	91.54
3.	Chipitola	8.2	1600	1024	56	44.88	13.64	555.29	69.23	-	-	408.96	51.02	18.64	88.52
4.	Kazipada	8.0	1600	1024	48	73.74	33.13	536.47	71.23	104	-	420.32	508.61	13.03	79.69
5.	Mamu Bhanja Ghatia	7.7	2900	1856	20	246.89	145.21	724.70	18.97	364	-	710.00	990.06	9.05	56.87
6.	Mantola Thana	7.4	2800	1792	16	243.68	144.23	743.52	20.00	78	-	704.32	964.55	9.33	57.76
7.	Charbagh	7.8	100	640	24	32.06	13.64	415.00	3.58	-	-	278.32	150.60	15.50	87.02
8.	Sorokatra	7.9	1000	640	28	35.27	14.64	415.00	4.61	-	-	266.96	200.81	14.84	85.99
9.	Teela Mattamal	7.3	1800	1152	96	153.90	70.17	517.64	11.79	156	-	613.44	385.16	8.68	62.91
10.	Purani Mandi	7.4	1800	1152	56	166.73	87.71	489.41	14.87	78	-	624.80	152.25	7.63	58.23
11.	Hanuman Chauraha	7.6	1500	960	48	33.66	8.77	630.58	7.69	182	-	323.76	188.46	25.05	92.00

12.	Kotla House	7.7	1500	960	52	12.82	4.87	630.58	8.71	39	130	318.08	213.98	38.04	96.37
13.	Swami Bagh	7.8	900	576	32	83.36	42.88	255.00	3.58	104	-	312.40	65.01	5.65	59.24
14.	Dayal Bagh	7.7	900	576	40	99.39	50.67	265.00	4.61	91	-	295.36	78.18	5.39	56.06
15.	Nunhai Chauraha	7.5	1800	1152	88	118.63	50.67	517.64	88.66	156	-	525.40	403.27	10.02	71.02
16.	Trans-Yamuna Colony	7.9	1700	1088	56	51.30	17.54	517.64	87.69	156	-	511.20	463.34	15.92	96.09
17.	Naubasta	7.8	2100	1344	112	28.85	9.74	649.41	11.79	-	104	528.24	440.30	26.70	92.72
18.	Telipada	7.9	2000	1280	88	19.23	9.74	130.58	13.84	65	78	550.96	384.34	29.24	94.04
19.	Idgah Bus Stand	8.3	3300	2112	112	173.14	77.96	818.82	18.97	78	-	1363.2	685.55	12.98	70.57
20.	M.S. Colony	7.4	3300	2112	64	179.55	93.56	1138.8	24.10	156	-	1351.8	747.28	17.17	75.07
21.	Samjay Place	8.9	1200	768	48	102.60	50.67	365.00	15.89	52	-	386.24	218.91	7.36	63.68
	Average	**7.8**	**1771.4**	**1133.7**	**58.09**	**94.96**	**45.9**	**552.7**	**24.8**	**135.7**	**104**	**536.24**	**366.23**	**15.2**	**76.31**

APPENDIX-III

Concentrations of Trace Elements in water samples (ppm) during premonsoon period (May- 2004)

S. No.	Sampling Locations	Cu	Zn	Fe	Cr	Mn	Co	Ni
1.	Lajpat Kunj	0.012	1.195	0.195	0.013	0.426	0.019	0.014
2.	Bharatpur House	0.002	0.037	0.205	0.011	0.020	0.018	0.012
3.	Chipitola	0.016	0.961	0.253	0.013	0.054	0.024	0.019
4.	Kazipada	0.007	0.476	0.132	0.012	0.020	0.024	0.013
5.	Mamu Bhanja Ghatia	0.013	1.772	0.110	0.033	0.037	0.038	0.028
6.	Mantola Thana	0.007	0.027	0.204	0.033	0.019	0.042	0.024
7.	Charbagh	0.006	0.045	0.157	0.005	0.024	0.013	0.011
8.	Sorokatra	0.0003	0.032	0.561	0.007	0.022	0.024	0.010
9.	Teela Mattamal	0.014	0.0104	0.183	0.015	0.036	0.024	0.019
10.	Purani Mandi	0.003	0.836	0.191	0.018	0.017	0.023	0.016
11.	Hanuman Chauraha	0.002	0.070	0.081	0.019	0.019	0.025	0.017

12.	Kotla House	0.002	0.940	0.188	0.019	0.012	0.026	0.015
13.	Swami Bagh	0.0001	2.380	0.034	0.006	0.022	0.016	0.011
14.	Dayal Bagh	0.001	1.139	0.363	0.010	0.013	0.017	0.009
15.	Nunhai Chauraha	0.003	1.730	0.304	0.017	0.023	0.027	0.017
16.	Trans-Yamuna Colony	0.002	0.107	0.212	0.017	0.028	0.027	0.017
17.	Naubasta	0.008	1.501	0.653	0.017	0.027	0.028	0.019
18.	Telipada	0.007	1.503	0.320	0.020	0.025	0.029	0.018
19.	Idgah Bus Stand	0.012	1.704	0.667	0.029	0.048	0.039	0.030
20.	M.S. Colony	0.011	2.472	0.367	0.027	0.174	0.037	0.025
21.	Samjay Place	0.003	0.078	0.383	0.012	0.042	0.023	0.016
	Average	**0.006**	**0.863**	**0.274**	**0.017**	**0.053**	**0.026**	**0.017**

APPENDIX-IV

Concentrations of Trace Elements in water samples (ppm) during postmonsoon period (Nov.- 2004)

S. No.	Sampling Locations	Cu	Zn	Fe	Cr	Mn	Co	Ni
1.	Lajpat Kunj	-	0.0715	0.138	0.665	0.084	0.076	0.086
2.	Bharatpur House	0.024	0.0958	0.188	0.248	0.063	-	0.171
3.	Chipitola	-	0.1108	0.188	0.748	0.021	0.015	0.279
4.	Kazipada	0.019	0.0612	0.225	0.165	0.084	0.015	0.171
5.	Mamu Bhanja Ghatia	0.019	0.6095	0.175	0.833	0.053	0.030	0.279
6.	Mantola Thana	0.043	0.3958	0.313	0.165	0.063	0.015	0.236
7.	Charbagh	0.014	0.7945	0.125	0.915	0.021	0.061	0.193
8.	Sorokatra	0.043	0.2528	0.175	0.165	0.053	-	0.149
9.	Teela Mattamal	0.019	0.5065	0.238	0.583	0.032	0.091	0.321
10.	Purani Mandi	0.024	0.5148	0.200	0.498	0.200	0.015	0.214
11.	Hanuman Chauraha	-	0.1040	0.150	0.498	0.042	0.030	0.149

12.	Kotla House	0.033	0.0810	0.088	0.248	0.063	-	0.171
13.	Swami Bagh	-	0.2133	0.138	0.665	0.032	0.030	0.279
14.	Dayal Bagh	0.028	0.1458	0.538	-	0.053	-	0.149
15.	Nunhai Chauraha	0.531	0.0462	0.113	0.583	0.053	0.030	0.257
16.	Trans-Yamuna Colony	0.445	0.3295	0.238	-	0.095	-	0.257
17.	Naubasta	0.009	0.0295	0.038	0.498	0.243	0.045	0.236
18.	Telipada	0.019	0.0688	0.025	0.165	0.274	-	0.129
19.	Idgah Bus Stand	0.009	0.6040	0.338	0.583	0.200	0.061	0.279
20.	M.S. Colony	-	0.6445	0.075	-	0.189	0.030	0.193
21.	Samjay Place	0.028	0.2378	0.325	-	0.158	-	0.214
	Average	**0.082**	**0.3278**	**0.192**	**0.484**	**0.099**	**0.039**	**0.210**